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Temperature and Current Measurements in St. Georges Bay, Nova Scotia, During 1979 and 1980

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by

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ABSTRACT

Drinkwater, K.F. 1991. Temperature and current measurements in St. Georges Bay, Nova Scotia, during 1979 and 1980. Can. Data Rep. Hydrogr. Ocean Sci. 98: iv + 44 pp.

A thermistor chain and current meter array was moored in St. Georges Bay from late April to early October of 1979. A single thermistor chain was also moored from mid-May to early October of 1980. The temperature and current data from these moorings are displayed graphically. In addition, the residual currents are determined along with the amplitude and phase of the M_2 tidal currents and the amplitude of the low-frequency (periods 2-10 d) current fluctuations.

RESUME

Drinkwater, K.F. 1991. Temperature and current measurements in St. Georges Bay, Nova Scotia, during 1979 and 1980. Can. Data Rep. Hydrogr. Ocean Sci. 98: iv + 44 pp.

On a mouillé un réseau de chaines de thermistances et de courantomètres dans la baie St. Georges de la fin d'avril au début d'octobre 1979. On y a également mouillé une chaine de thermistances seule, de la mi-mai au début d'octobre 1980. Le lecteur trouvera ici la représentation graphique des données sur les températures et les courants fournies par ces instruments. Il trouvera également des donées sur les courants résiduels, sur l'amplitude et sur la phase des courants de marée M_2, ainsi que sur l'amplitude des fluctuations de courant aux basses fréquences (périodes de 2 à 10 j).

INTRODUCTION

During the 1970s extensive field studies were undertaken by scientists from the Bedford Institute of Oceanography to determine the abiotic and biotic factors influencing the growth and survival of fish larvae (Hargrave et al. 1985). The initial physical oceanographic studies, undertaken as part of that program, concentrated upon the residual circulation and a description of the current variability (Petrie and Drinkwater 1978a,b). The current meter data suggested the possible importance of wind forcing but a simple relationship could not be established (Petrie and Drinkwater 1978a). In 1979, a thermistor chain and current meter array was deployed in the Bay for over 6 months with the aim of examining the dynamics of wind forcing. A detailed analysis of these data can be found in Drinkwater (1987). In 1980 a single thermistor chain was deployed for 4 months to provide additional temperature data as well as background information for biological studies conducted that year. The present data report provides a graphical presentation of the moored temperature and current data collected in both 1979 and 1980 together with some statistical properties of the currents.

STUDY AREA AND MOORING SITES

St. Georges Bay is located in the southern Gulf of St. Lawrence. It is surrounded on 3 sides by mainland Nova Scotia and Cape Breton Island but is open on the north to Northumberland Strait (Fig. 1). The Bay is shallow (mean depth of 24 m) with a maximum depth of 40 m and has an area of approximately 900 km^2.

In 1979 a thermistor chain was deployed at site T1 on 27 April and was removed on 2 November. Three additional thermistor chains were deployed on 3 July at sites T2, T3, and T4. A current meter was also placed on the T2 mooring at 32 m, 1 m off bottom. Two current meters were placed at T3, one at 7 m from the surface and the other 1 m off bottom at 24 m depth. Instruments at sites T3 and T4 were recovered on 4 September. The mooring at T2 was

prematurely recovered by a fisherman on 17 August. In 1980 a thermistor chain was deployed at site T1 on 12 May and was recovered on 8 October. Each thermistor chain contained 11 thermistors and the approximate depths at each site are listed in Table 1. The relative depths between thermistors were accurately measured on land prior to deployment and the absolute depths determined from the station depth as recorded on the ship's sounder. The estimated uncertainty in the absolute depths are ± 1 m.

The summary of mooring periods and data return is given in Fig. 2. Instrument failures at T1 resulted in approximately 8 days loss of data in October, 1979, and only partial data recovery during the last 21 days in 1980. With these exceptions, the data from both the thermistor chains and current meters were of high quality.

All instruments were manufactured by Aanderaa. Tests in water baths conducted at the Bedford Institute generally indicated an accuracy for the thermistor chains of ± 0.05°C (R. Boyce, Bedford Institute, personal communication). The accuracy of the Aanderaa RCM5 current meters has been estimated from labratory tests to be ± 1.3% or 0.005 m s^{-1} in amplitude, with a minimum threshold of 0.02 m s^{-1} (Tang and Hartling 1979), and ± 5° in direction (Keenan 1979). However, in the presence of surface waves these instruments tend to over estimate the water velocity although intercomparison with vector averaging current meters have failed to find a consistent relationship between the degree of contamination and strength of forcing (Smith et al. 1984). Temperature and salinity sensors on the current meters have accuracies estimated to be ± 0.04°C and ± 0.11 in salinity (Boyce 1982).

DATA ANALYSIS

Temperature Measurements

The thermistor data were recorded every 20 minutes in 1979 and every 15 minutes in 1980. These records were then filtered

using a 5-point equally-weighted running mean and reduced to hourly values. The time series plots of the temperature at individual depths for each station are shown in Fig. 3 through Fig. 7. The combined data for all depths at T1 are plotted for both 1979 and 1980 are plotted in Fig. 8 and 9. A low pass Cartwright filter was then applied with a 50% power reduction at a period of 32 hr and 99.9% reduction at 24 hr. The resultant filtered data were reduced to daily values. Isotherm depths were calculated using linear interpolation of the low-pass filtered data and are plotted for each site (Fig. 10-12). The daily data were then averaged by month. The monthly means and standard deviations at each depth for site T1 in 1979 and 1980 are listed in Tables 2 and 3, respectively. Vertical profiles of the monthly means at T1 are plotted in Fig. 13.

Current Measurements

The current data were recorded every 10 minutes, filtered using a 7-point running mean, and reduced to hourly values. For each station and depth, plots were produced of the hourly rates, directions, temperatures, salinities and velocity components (u positive eastward, v positive northward). The low pass filter described above was applied and the data were reduced to 6 hourly values for plotting of progressive vector and stick diagrams. The progressive vector diagrams show the path a parcel of water would travel if it was subject to the currents measured at the current meter site. The lines in the stick plots point in the direction the current is moving towards. The plots for site T2 (32 m) appear in Fig. 14 through 17, T3 (7 m) in Fig. 18 through 21, and T2 (24 m) in Fig. 22 through 25.

A harmonic analysis of the tides was performed using a least squares fit of the hourly data to the frequency of the major tidal constituents. The amplitudes and phases for the M_2 component, the major tidal constituent, are found in Table 4. The mean residual currents were calculated from the daily low-pass filtered data and are listed together with their standard deviations and the error of the means in Table 5. The error of the means was calculated by

dividing the standard deviation by the square root of the number of independent points. The latter was estimated from the number of daily values and the autocorrelation of the time series following Bayley and Hammersley (1946). The 95% confidence limits about the mean are approximately 2 times the error of the mean. The mean currents at T2 and T3 were very weak and only near bottom at T3 are the mean currents considered significantly different from zero.

Spectra were calculated from the hourly current data. The average rms (root-mean-square) amplitudes of the low-frequency currents (periods 2-10 d) were determined from the spectra and are listed in Table 6.

ACKNOWLEDGEMENTS

I would like to thank the many people who contributed to this study. The mooring program in 1979 was designed with input from C. Garrett, T. Bowen and B. Petrie and was deployed by D. Dobson and G. Taylor. Thanks are especially due the Captain and crew of the *Navicula*. Comments on the original manuscript by B. Petrie and G. Bugden were greatly appreciated.

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TABLE 1. The thermistor depths (m).

	1979				1980
Station	T1	T2	T3	T4	T1
	5.0	7.5	8.0	8.5	5.0
	7.0	10.0	9.0	9.5	8.0
	10.0	12.5	10.5	11.0	11.0
	13.0	15.0	12.0	12.5	14.0
	16.0	17.5	13.5	14.0	17.0
	19.0	20.0	15.0	15.5	20.0
	22.0	22.5	16.5	17.0	23.0
	25.0	25.0	18.0	18.5	26.0
	28.0	27.0	19.5	20.0	29.0
	29.5	29.0	21.0	21.5	32.0
	31.0	31.0	23.0	23.0	34.5
BOTTOM DEPTH	31.0	33.0	25.0	23.0	34.5

TABLE 2. The monthly mean temperatures, their standard deviations, and the number of days of data at T1 for 1979.

1979

Depth	Apr	May	Jun	Jul	Aug	Sep	Oct
5	3.6	6.2	12.5	17.0	18.9	16.8	14.7
	1.0	1.6	1.8	1.8	1.1	1.3	0.1
7	3.2	5.9	12.1	16.7	18.8	16.8	14.6
	1.5	1.4	2.0	1.8	1.0	1.4	0.1
10	2.7	5.3	11.3	16.2	18.5	16.6	14.5
	1.4	1.0	2.6	1.7	0.7	1.4	0.1
13	1.6	4.5	10.1	15.0	17.8	16.5	14.4
	0.2	0.9	3.0	1.3	0.9	1.4	0.1
16	0.3	3.7	8.8	13.9	17.0	16.5	14.4
	0.5	1.3	3.1	1.4	1.5	1.3	0.1
19	-0.6	2.9	6.9	13.0	15.6	16.0	14.3
	0.3	1.5	2.6	2.0	2.5	1.2	0.1
22	-1.0	2.1	5.2	11.6	13.5	14.7	14.2
	0.3	1.7	1.9	2.6	3.4	1.7	0.2
25	-1.3	1.4	3.8	9.4	10.4	12.4	14.0
	0.1	1.6	1.5	3.2	3.6	2.8	0.3
28	-1.4	0.8	2.7	6.8	7.4	8.9	13.4
	<0.1	1.4	1.1	2.9	3.0	3.5	0.8
29.5	-1.4	0.5	2.3	5.7	6.2	7.4	12.8
	<0.1	1.5	1.0	2.4	2.5	3.1	1.0
31	-1.4	0.2	2.0	4.8	4.8	5.1	11.4
	<0.1	1.3	0.8	1.9	1.9	1.5	0.6
# of days	3	31	30	31	31	30	3

TABLE 3. The monthly mean temperatures, their standard deviations, and the number of days of data at T1 for 1980.

1980

Depth	Apr	May	Jun	Jul	Aug	Sep	Oct
5		5.5	10.2	15.3	18.4	17.7	
		1.0	2.1	1.6	0.7	0.5	
8		5.2	9.9	14.9	18.2	17.7	
		1.0	2.0	1.5	0.5	0.5	
11		4.8	9.6	14.4	17.7	17.7	
		1.0	2.0	1.0	0.7	0.5	
14		4.4	9.3	13.9	17.0	17.7	
		1.0	2.2	0.5	1.4	0.5	
17		3.8	8.8	13.5	16.2	17.7	
		1.3	2.3	0.4	1.9	0.5	
20		3.2	7.7	13.1	15.3	17.6	
		1.5	2.4	0.6	2.3	0.5	
23		2.6	6.1	12.5	14.1	17.5	
		1.7	2.3	1.0	3.3	0.6	
26		1.9	4.5	11.0	12.4	17.4	
		1.8	2.6	1.7	4.2	0.7	
29		0.8	3.3	8.3	10.6	16.9	
		1.3	2.7	2.6	4.5	1.1	
32		-0.2	2.3	6.2	8.5	14.3	
		0.4	1.9	2.7	3.9	2.1	
34.5		-0.5	1.3	5.0	6.2	10.0	
		0.1	0.8	2.1	2.7	1.9	
# of days		17	30	31	31	16	

TABLE 4. The amplitude (in 10^{-2} m s^{-1}) and phase (referenced to Universal Time) of the M_2 tidal constituents for the 1979 current meter data.

Stn.	Depth	U		V	
		Amp.	Phase	Amp.	Phase
T2	32	1.7	53	0.7	163
T3	7	1.1	129	1.2	142
	24	1.0	67	0.3	120

TABLE 5. The mean, standard deviation (SD) and error of the mean (ϵ) for the velocity components in 10^{-2} m s^{-1}. The mean rate (R) and direction (D) are also provided.

Stn.	Depth	U	SD	ϵ	V	SD	ϵ	R	D
T2	32	0.2	1.2	0.2	-0.6	4.9	0.8	0.6	162
T3	7	-0.5	9.8	2.0	0.6	4.9	0.8	0.8	320
	24	0.6*	1.9	0.2	-0.5*	1.3	0.2	0.8	130

* Significantly different from 0 at the 95% confidence level.

TABLE 6. The average rms amplitude in 10^{-2} m s^{-1} of the low frequency velocity components (periods 2-10 d). The speed is defined as the square root of $U^2 + V^2$.

Stn.	Depth	U	V	Speed
T2	32	0.8	3.2	3.3
T3	7	5.0	2.8	5.8
	24	1.8	0.9	2.0

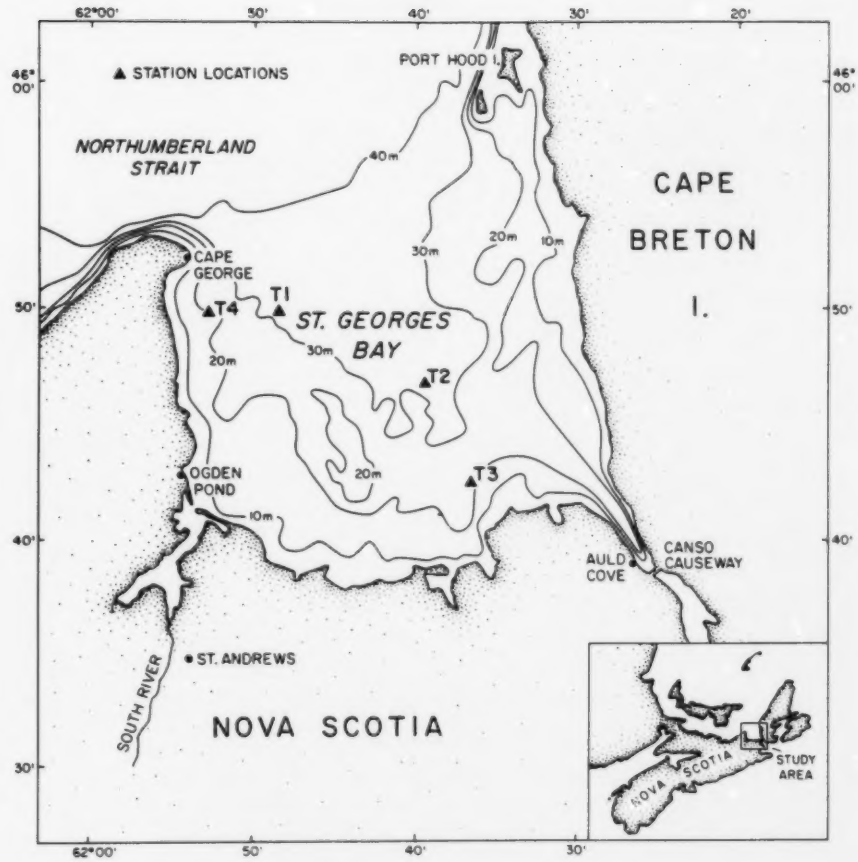

Fig. 1. St. Georges Bay showing the location of the thermistor and current meter stations T1 to T4.

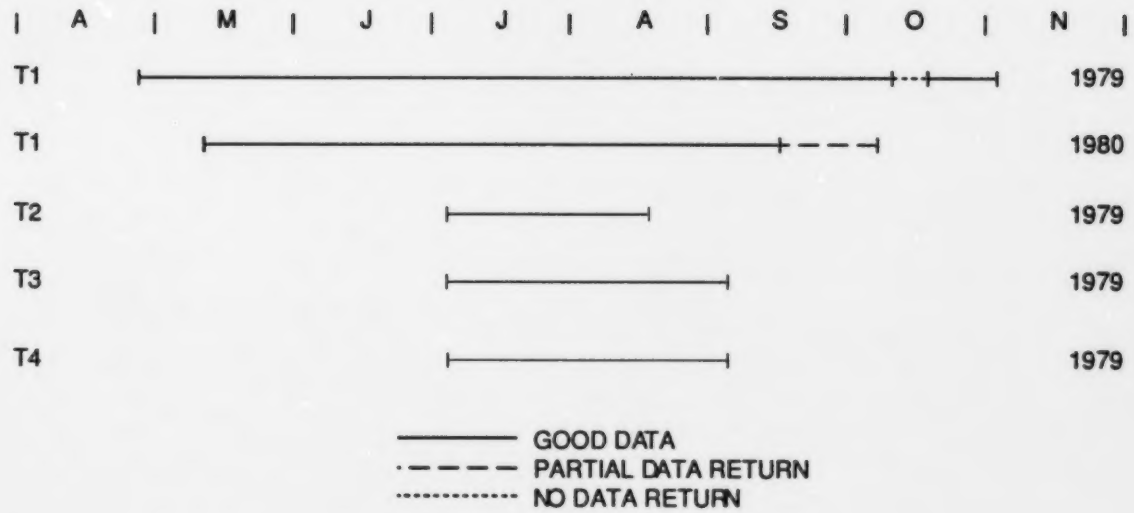

Fig. 2. Mooring periods and instrument performance.

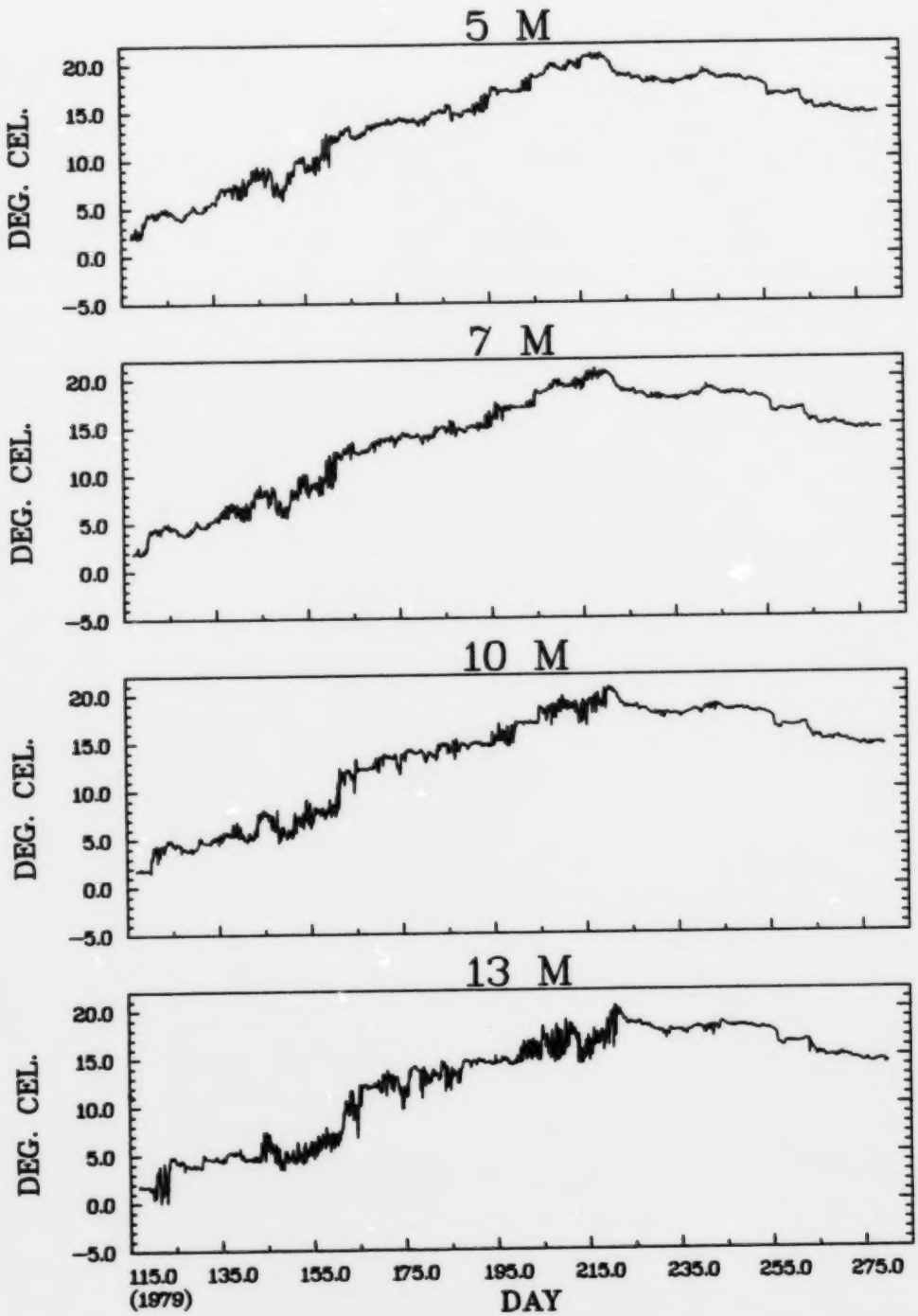

Fig. 3a. Temperature time series at 5, 7, 10, and 13 m at T1, 1979. The time axis is in Julian days (Day 115 is April 25).

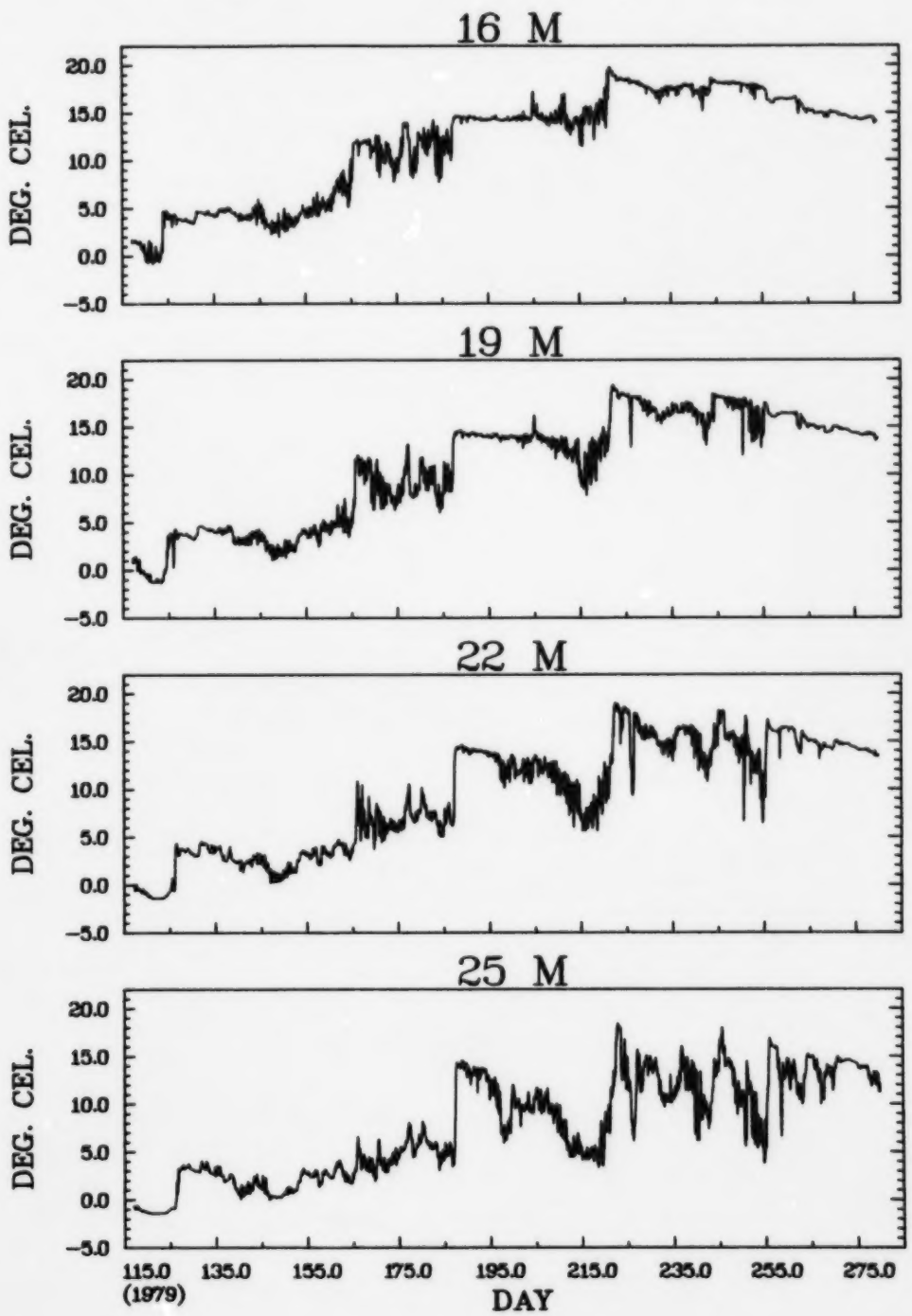

Fig. 3b. Temperature time series at 16, 19, 22, and 25 m at T1, 1979.

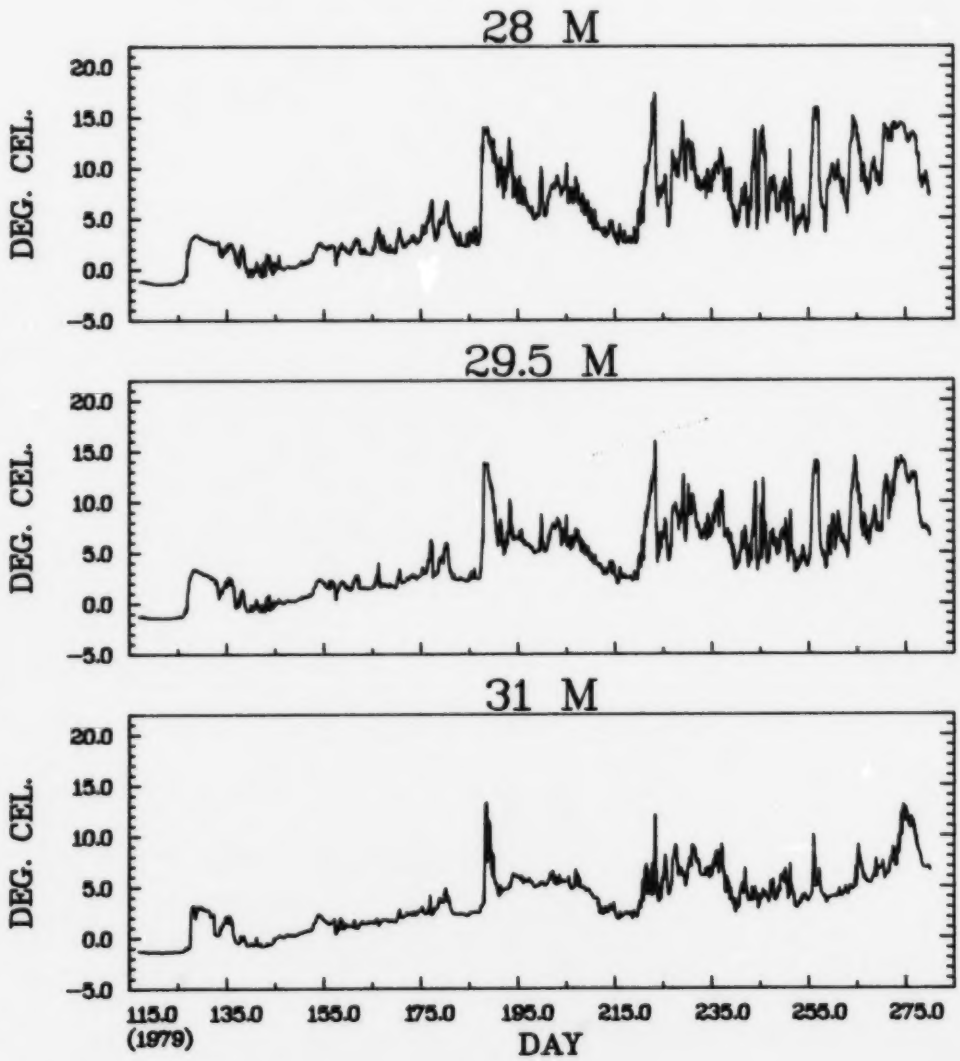

Fig. 3c. Temperature time series at 28, 29.5, and 25 m at T1, 1979.

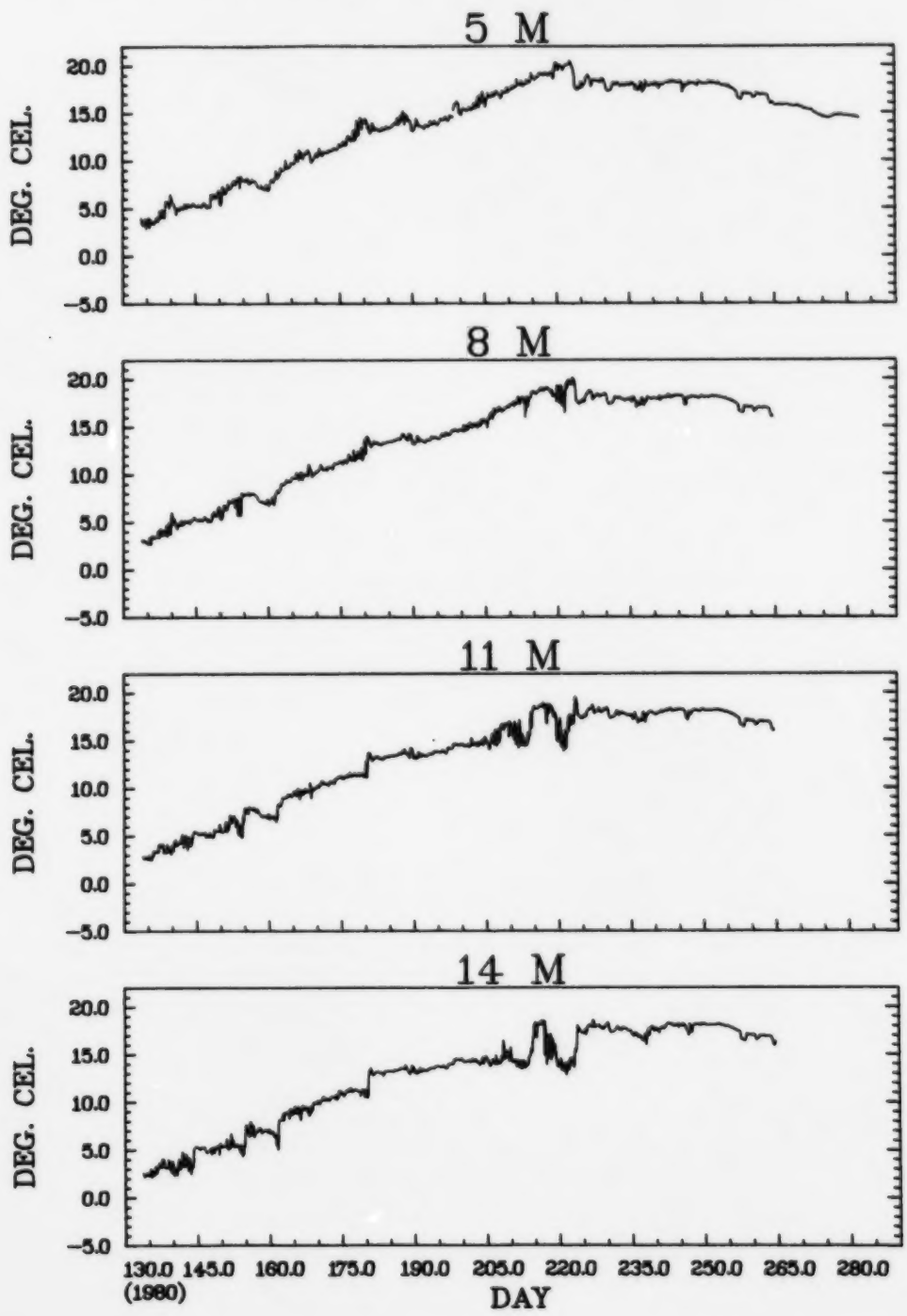

Fig. 4a. Temperature time series at 5, 8, 11, and 14 m at T1, 1980. The time axis is in Julian days (day 130 is May 9).

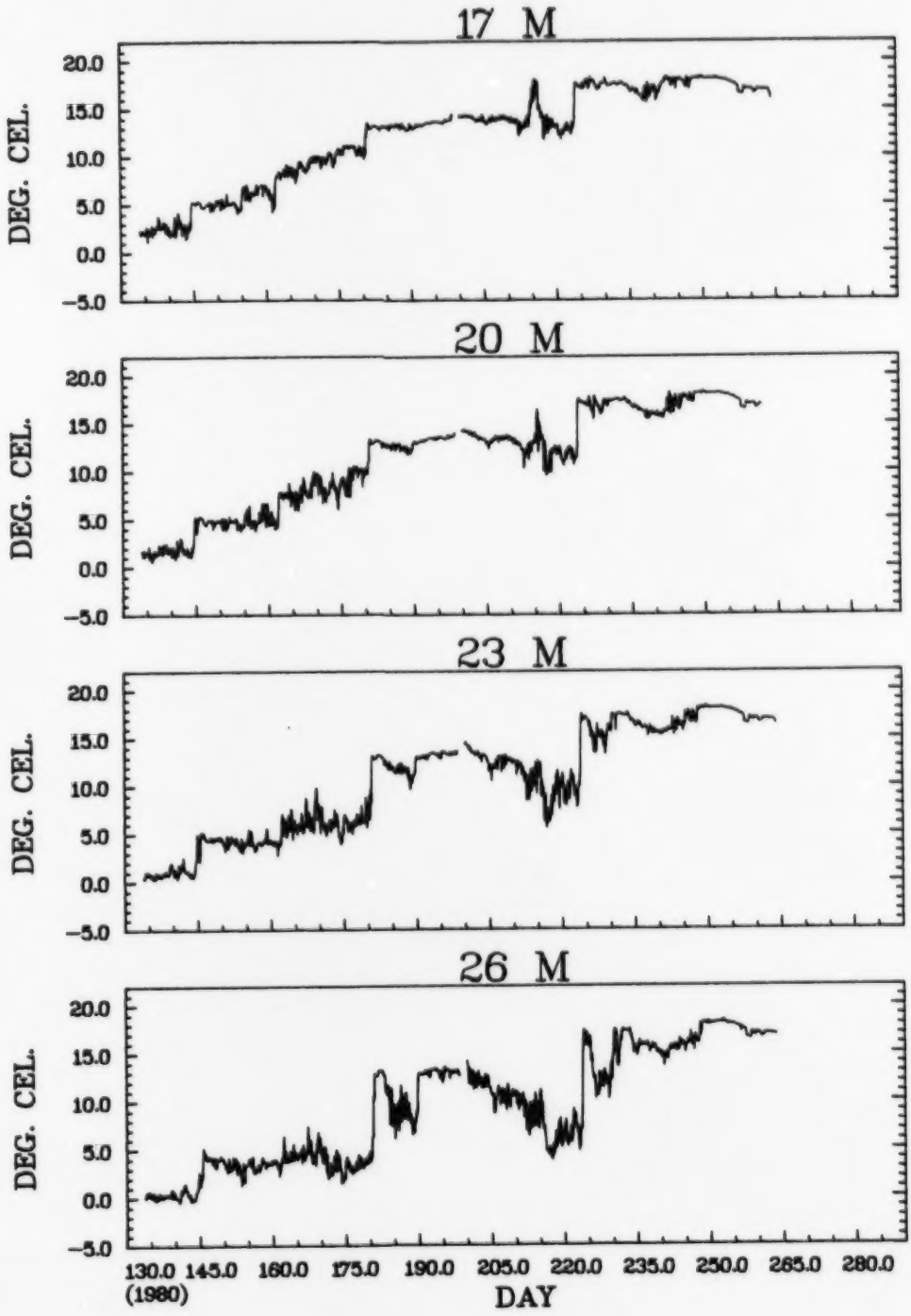

Fig. 4b. Temperature time series at 17, 20, 23, and 26 m at T1, 1980.

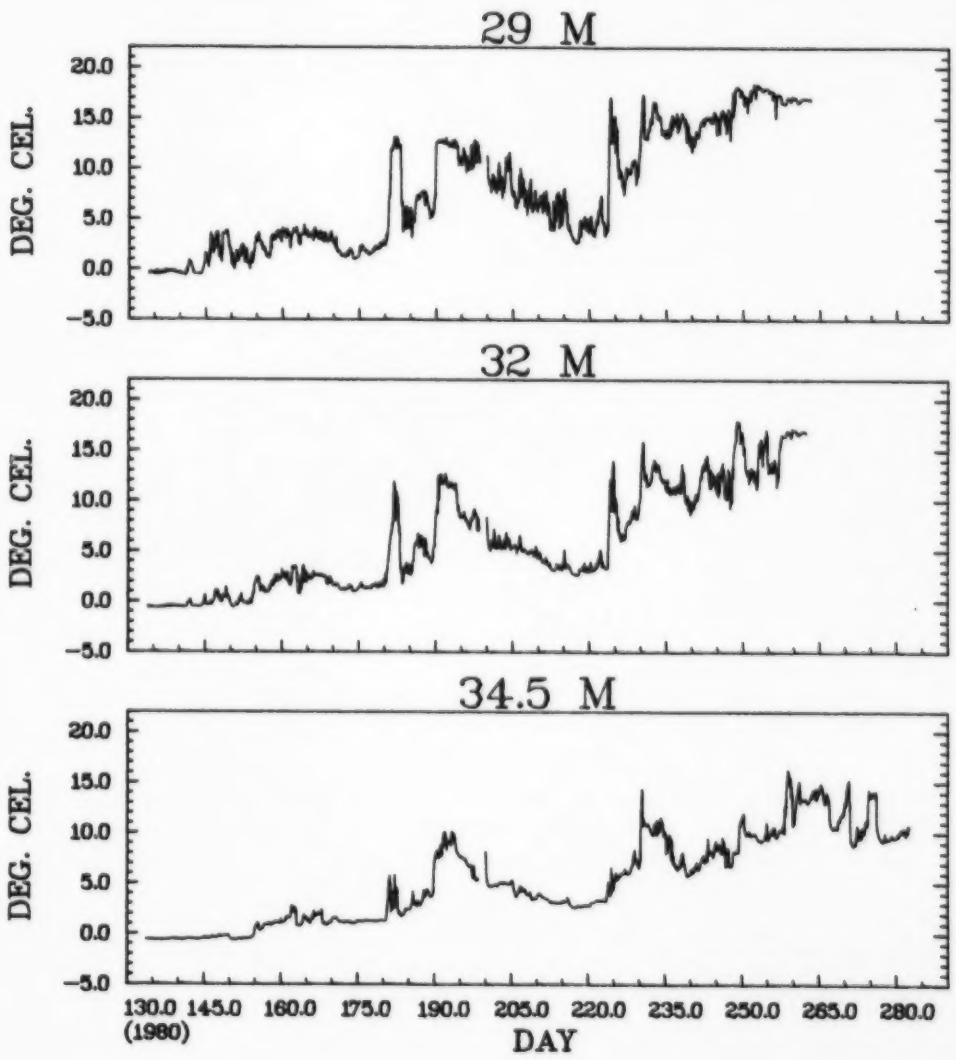

Fig. 4c. Temperature time series at 29, 32, and 34.5 m at T1, 1980.

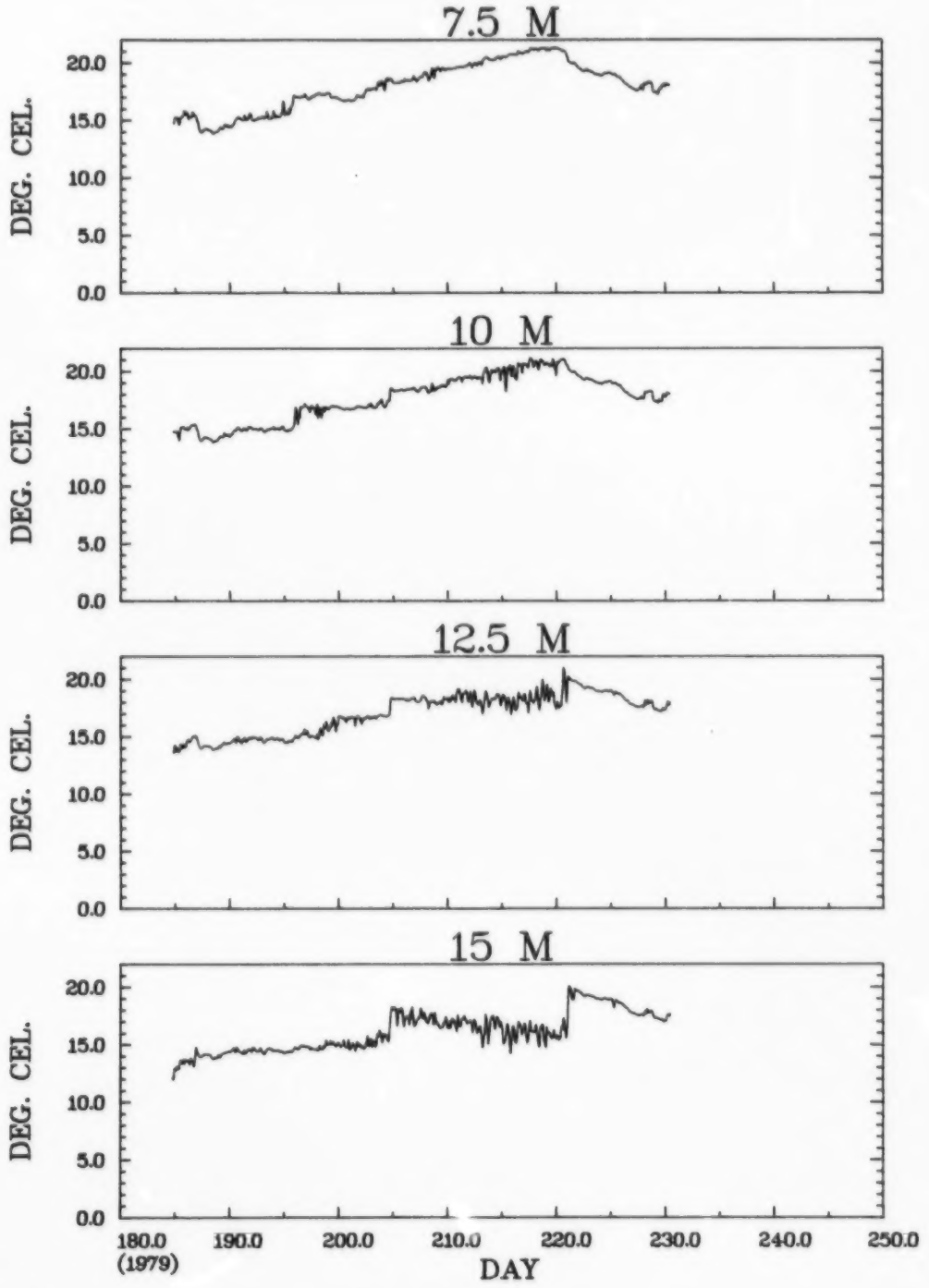

Fig. 5a. Temperature time series at 7.5, 10, 12.5, and 15 m at T2, 1979. The time axis is in Julian days (day 180 is June 29)

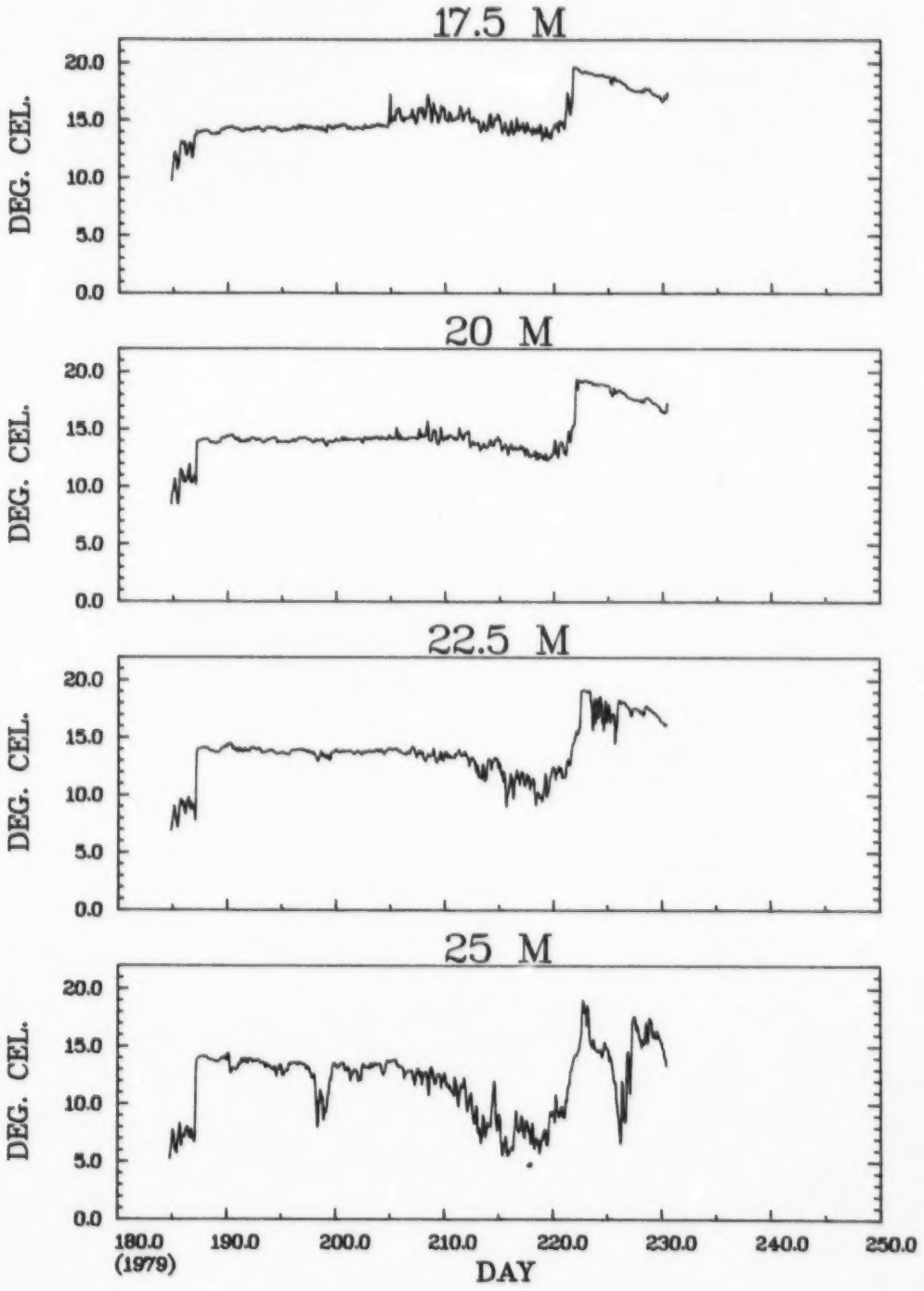

Fig. 5b. Temperature time series at 17.5, 20, 22.5, and 25 m at T2, 1979.

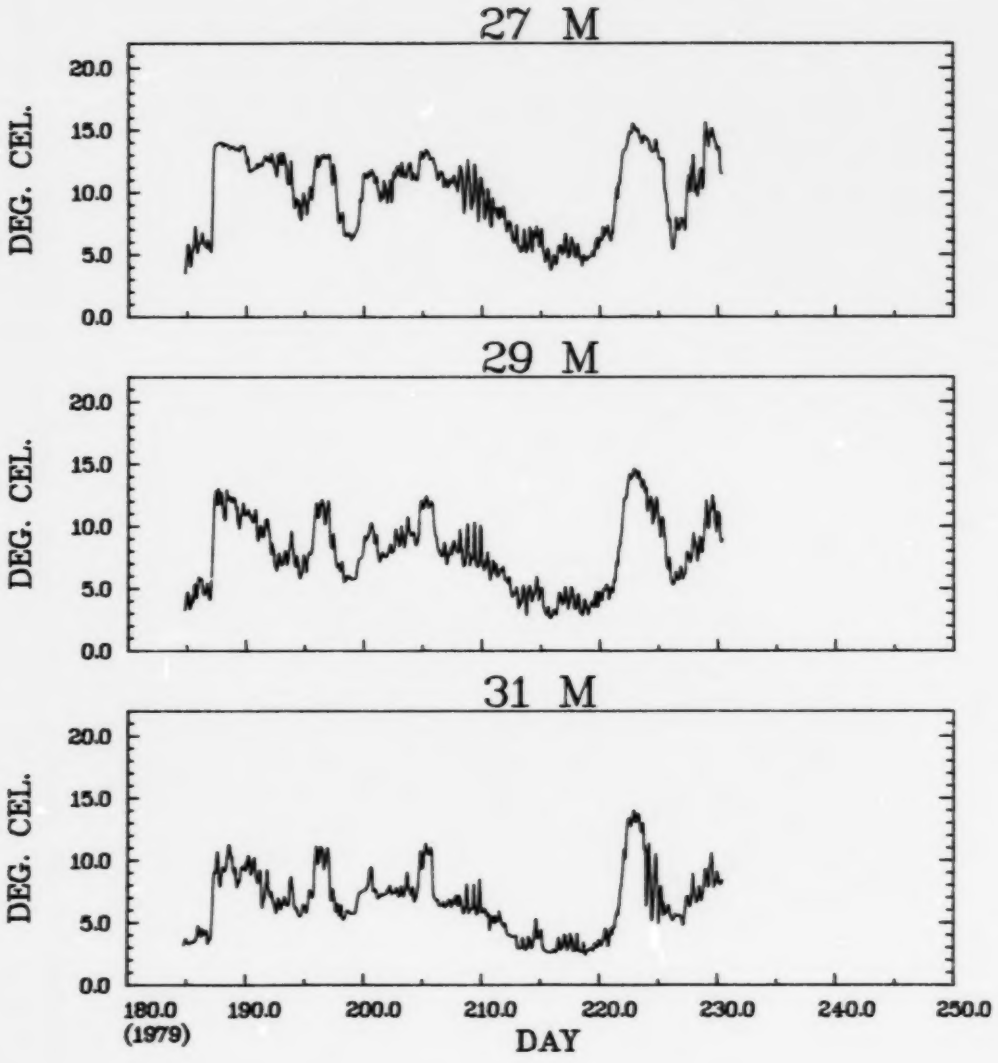

Fig. 5c. Temperature time series at 27, 29, and 31 m at T2, 1979.

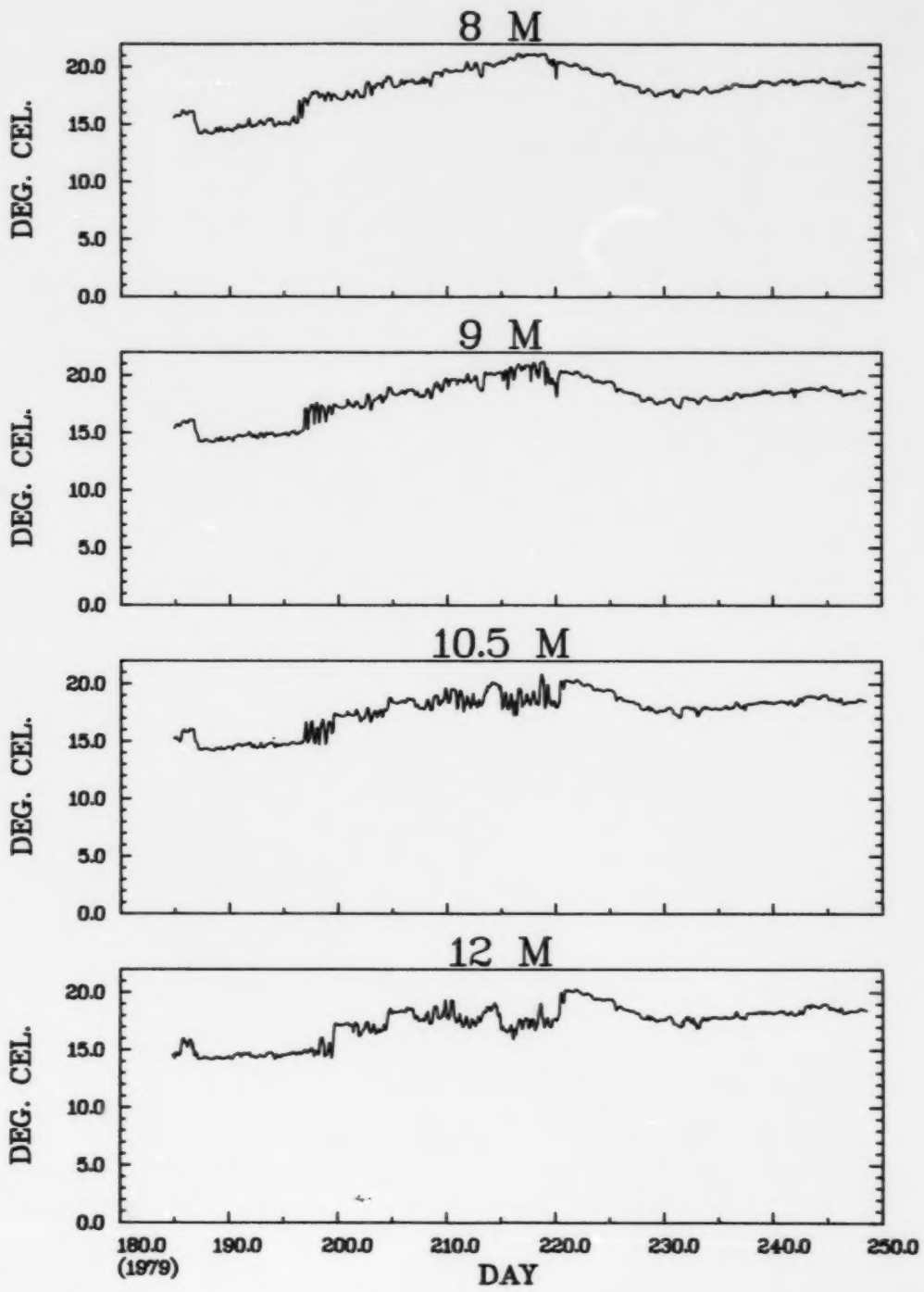

Fig. 6a. Temperature time series at 8, 9, 10.5, and 12 m at T3, 1979. The time axis is in Julian days (day 180 is June 29).

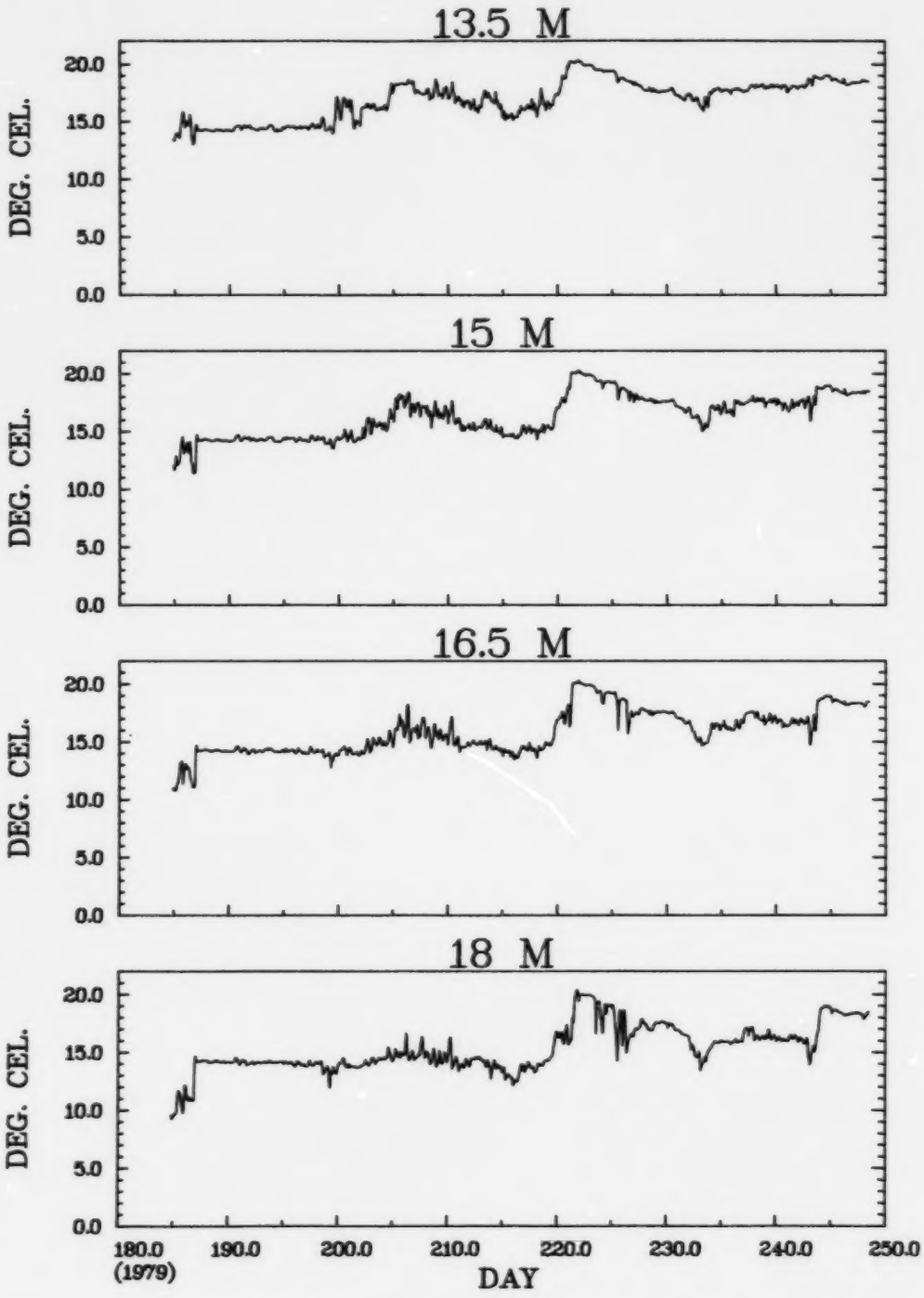

Fig. 6b. Temperature time series at 13.5, 15, 16.5, and 18 m at T3, 1979.

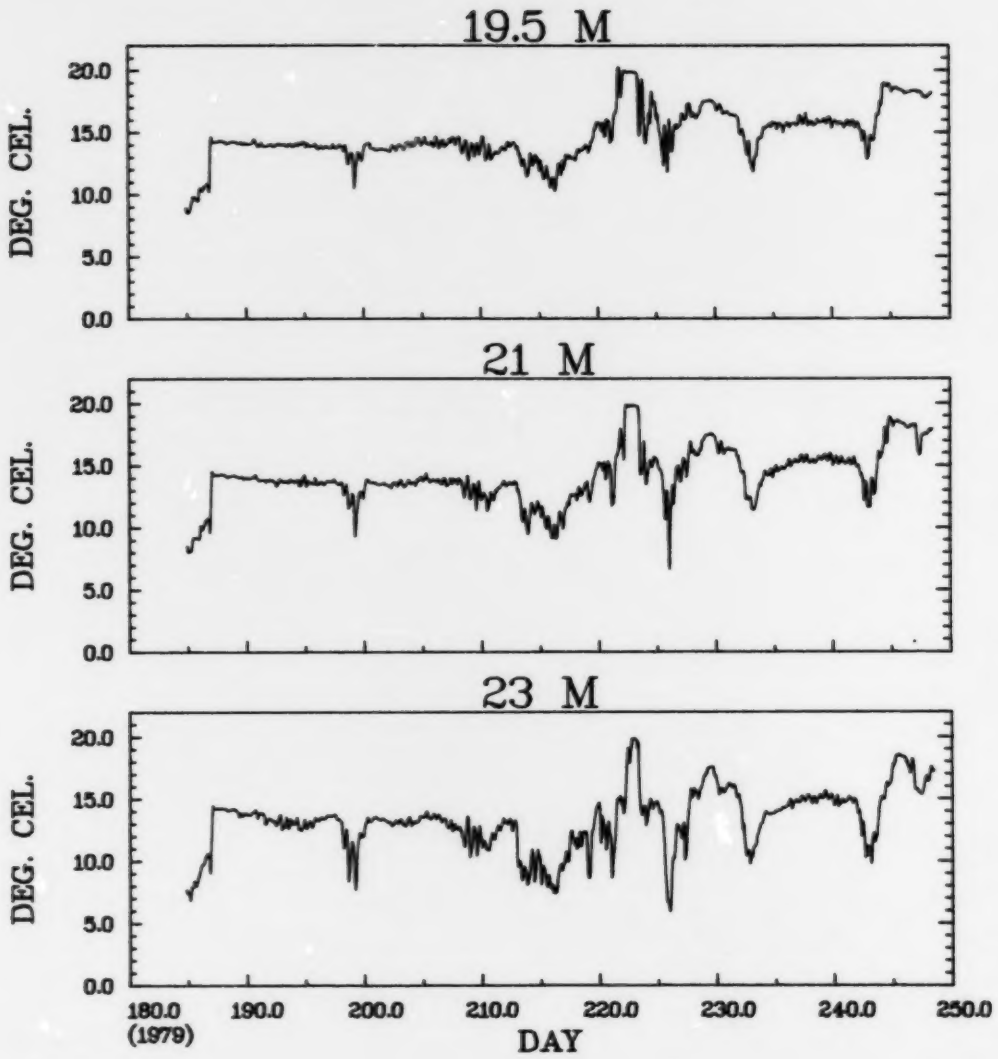

Fig. 6c. Temperature time series at 19.5, 21, and 23 m at T3, 1979.

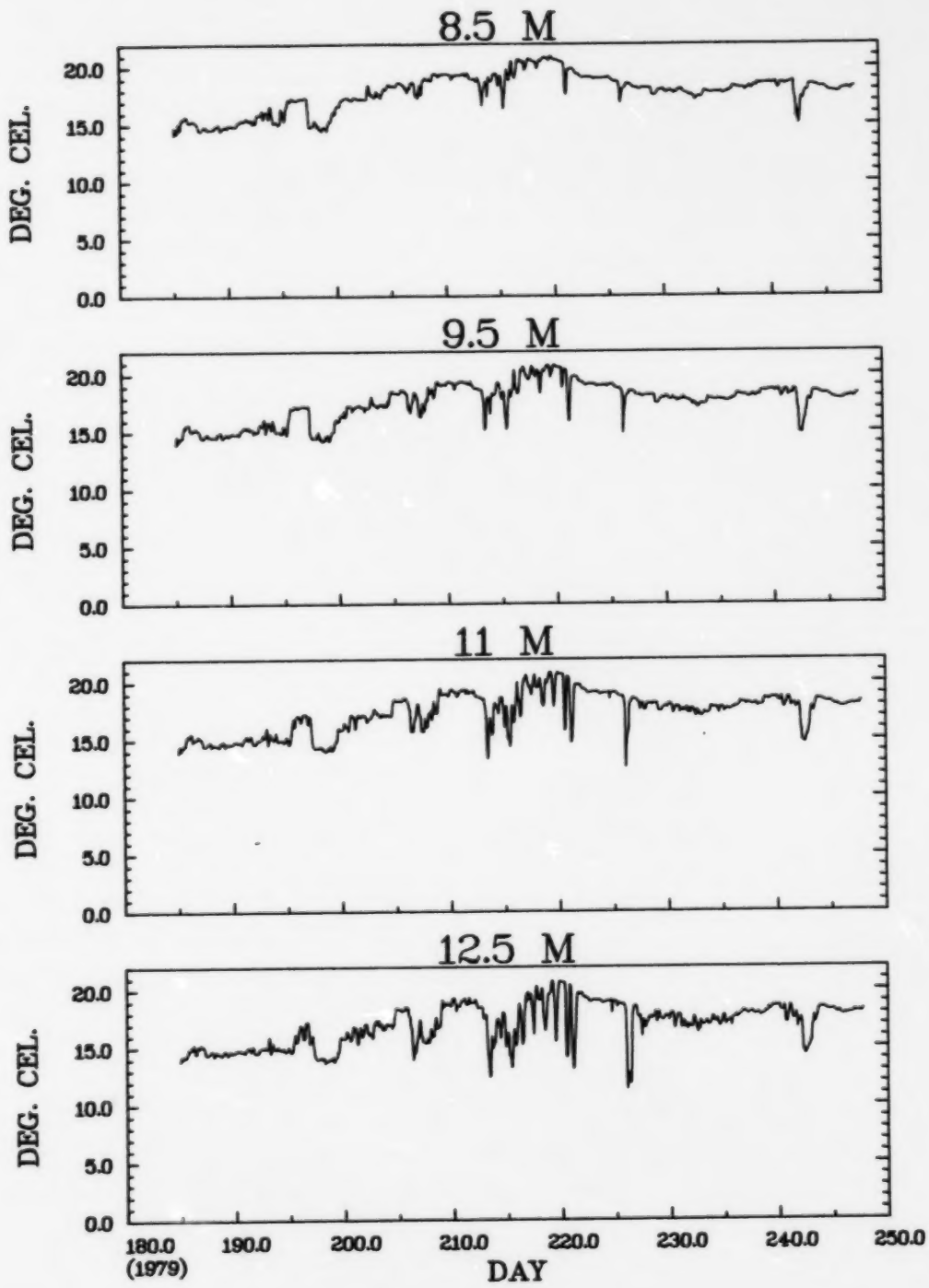

Fig. 7a. Temperature time series at 8.5, 9.5, 11, and 12.5 m at T4, 1979. The time axis is in Julian days (day 180 is June 29).

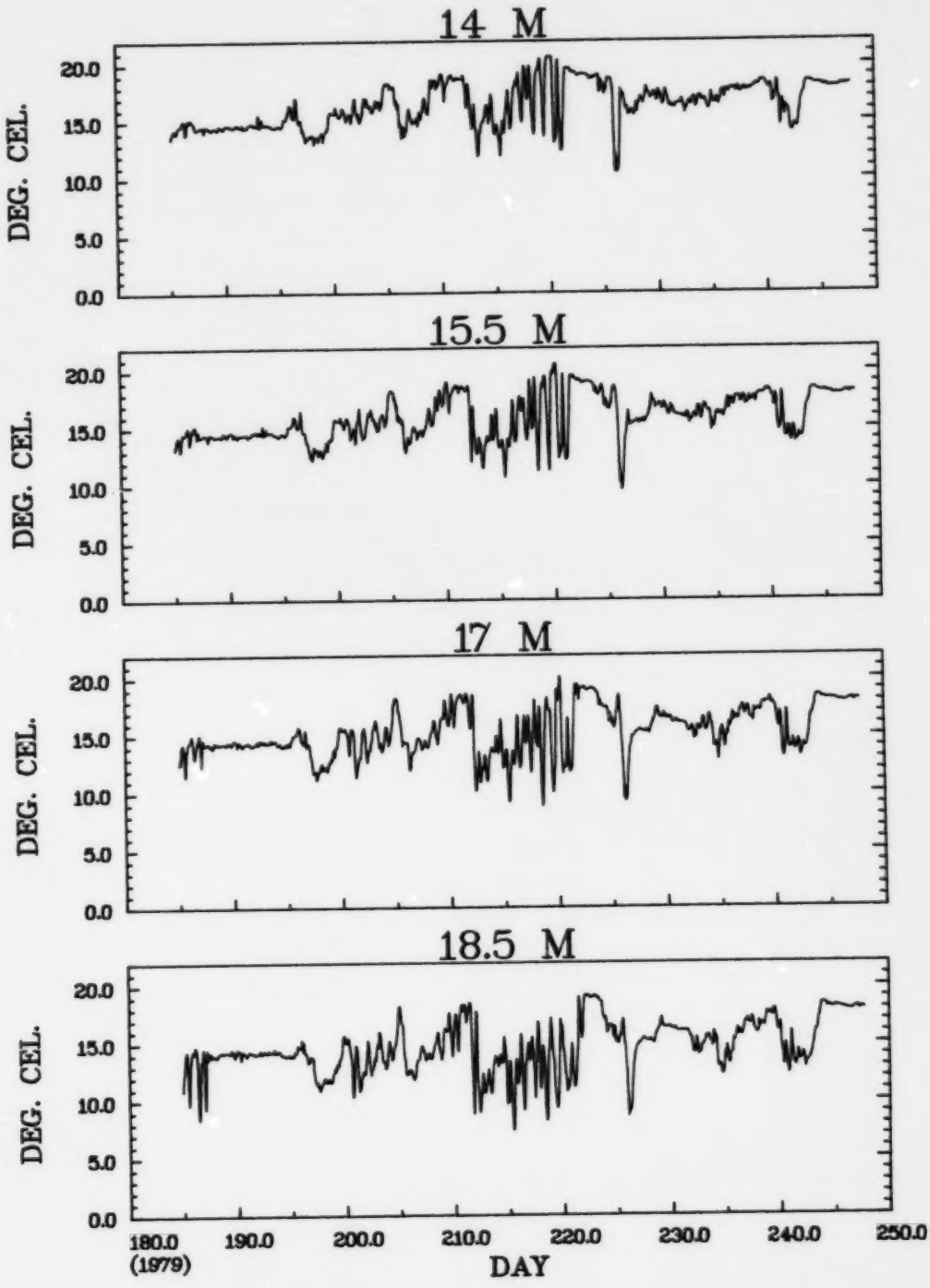

Fig. 7b. Temperature time series at 14, 15.5, 17, and 18.5 m at T4, 1979.

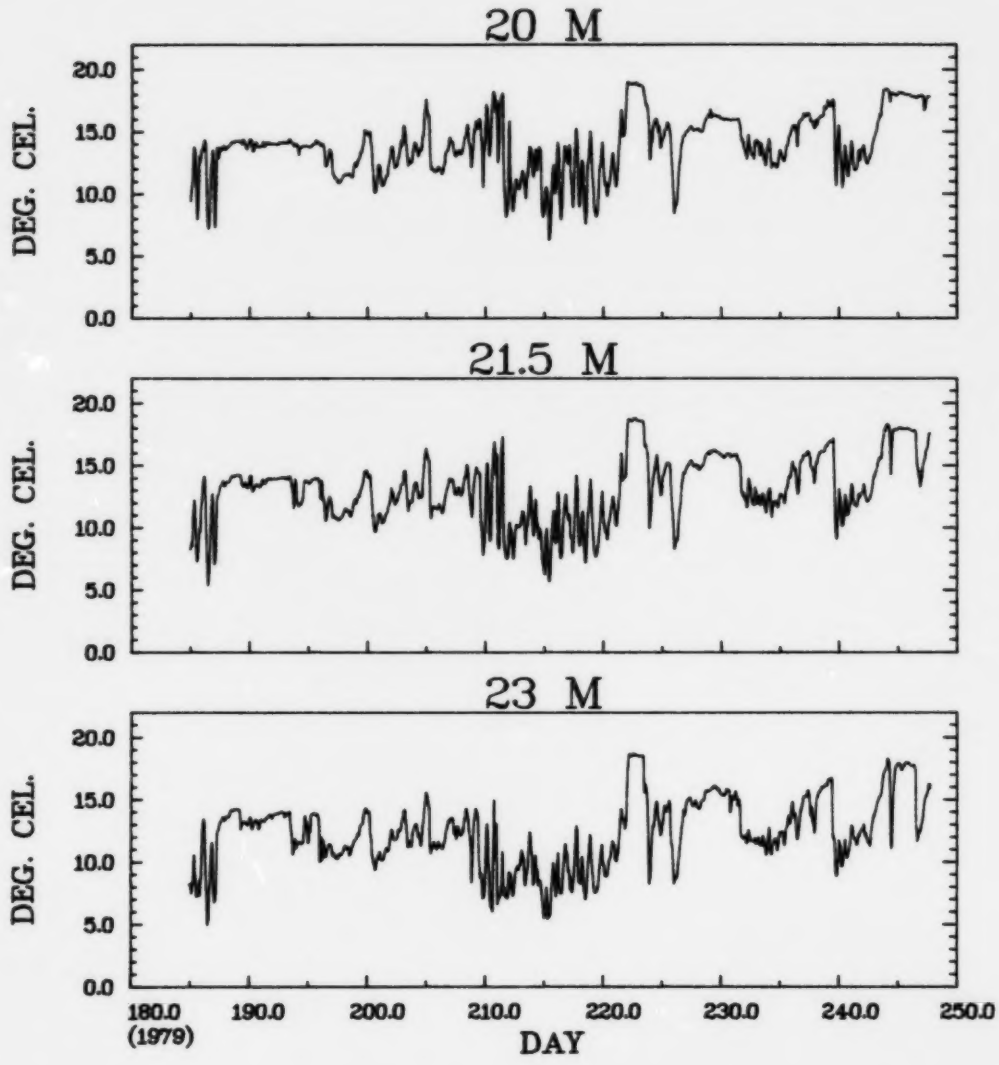

Fig. 7c. Temperature time series at 20, 21.5, and 23 m at T4, 1979.

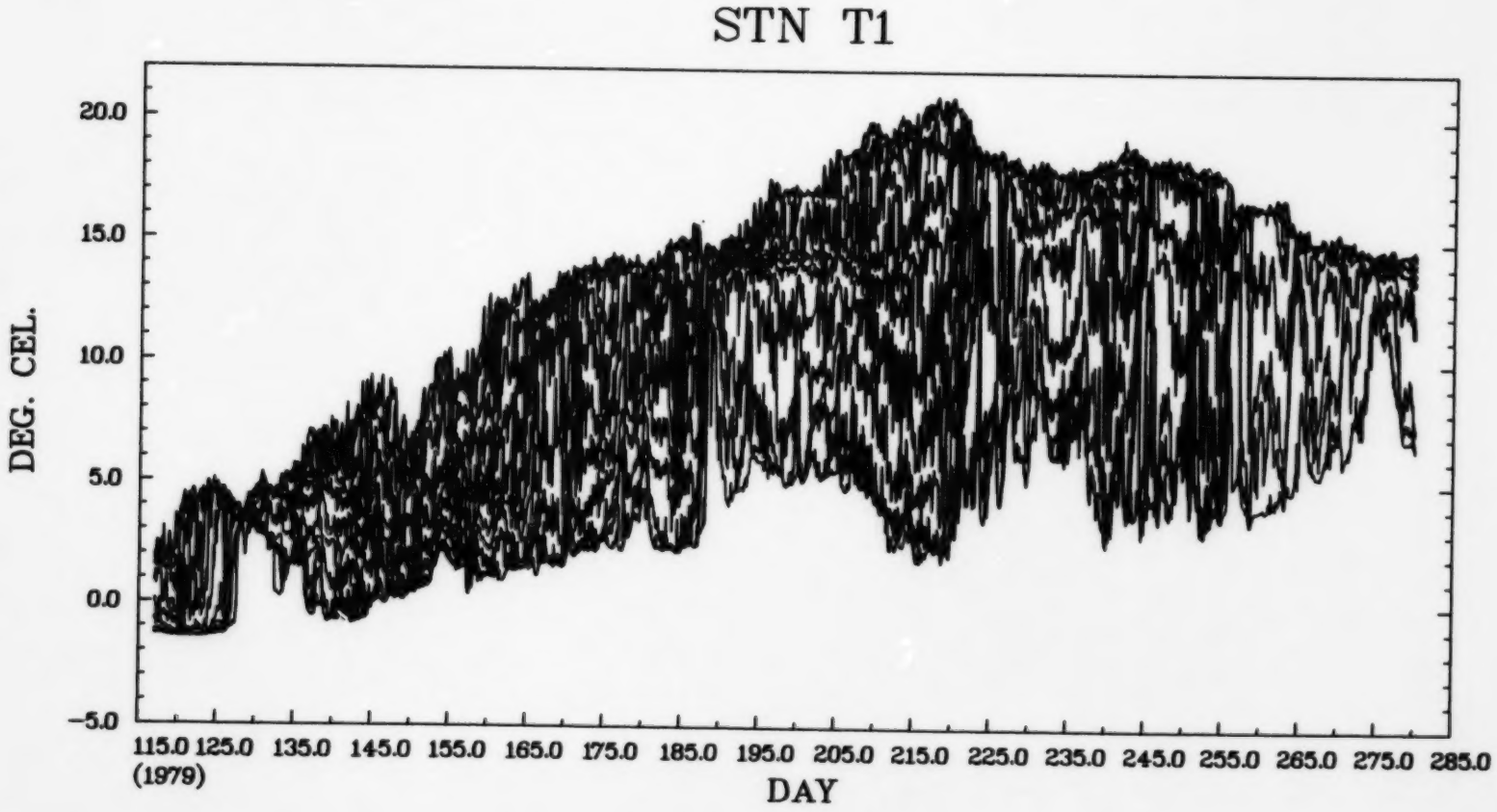

Fig. 8. Time series of temperatures during 1979 at T1 for all depths showing the variability in the vertical thermal stratification. The time axis is in Julian days (day 115 is April 25).

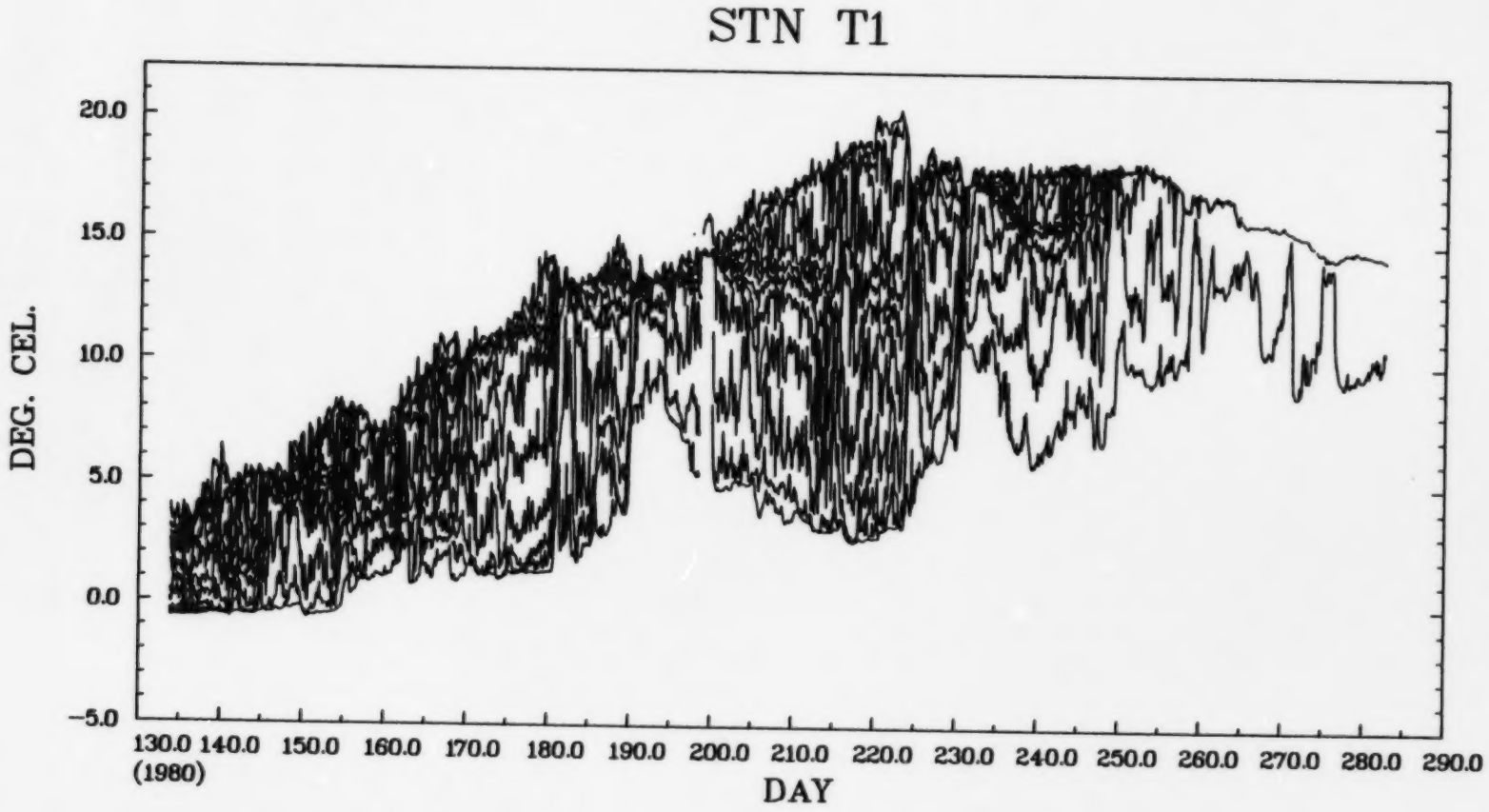

Fig. 9. Time series of temperatures during 1980 at T1 for all depths showing the variability in the vertical thermal stratification. The time axis is in Julian days (day 130 is May 9).

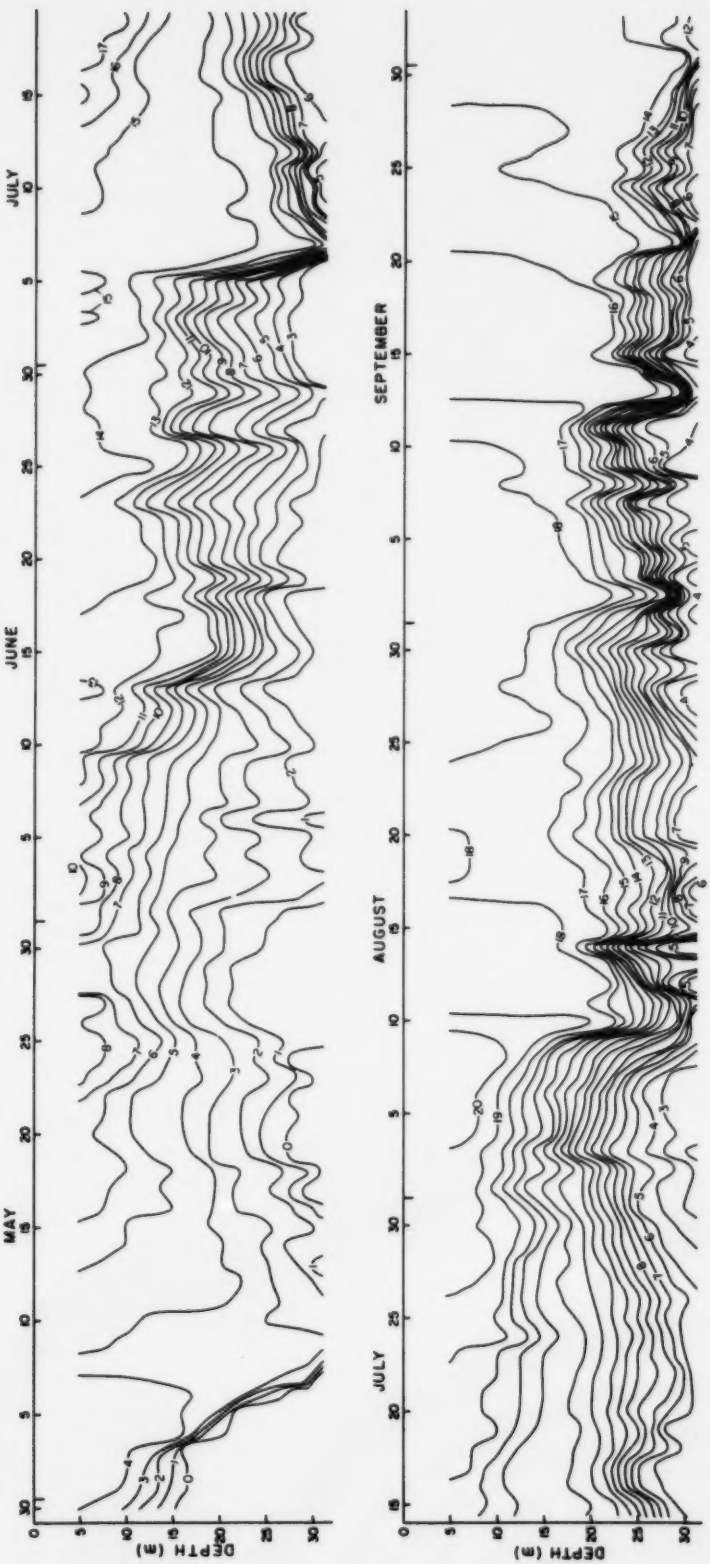

Fig. 10. The variability in the depth of the isotherms during 1979 at T1.

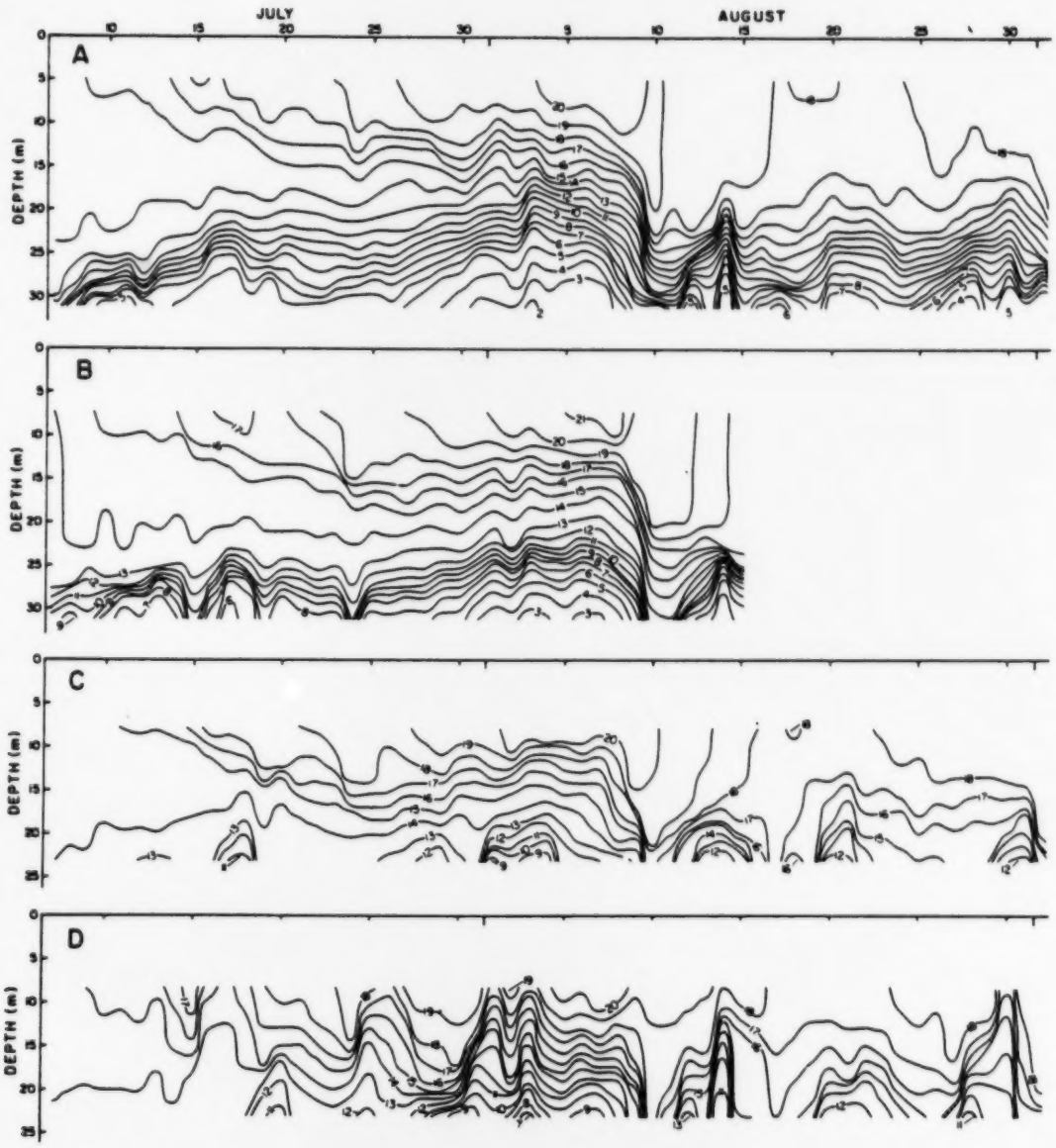

Fig. 11. The variability in the depth of the isotherms during the summer of 1979 at (A) T1, (B) T2, (C) T3, and (D) T4.

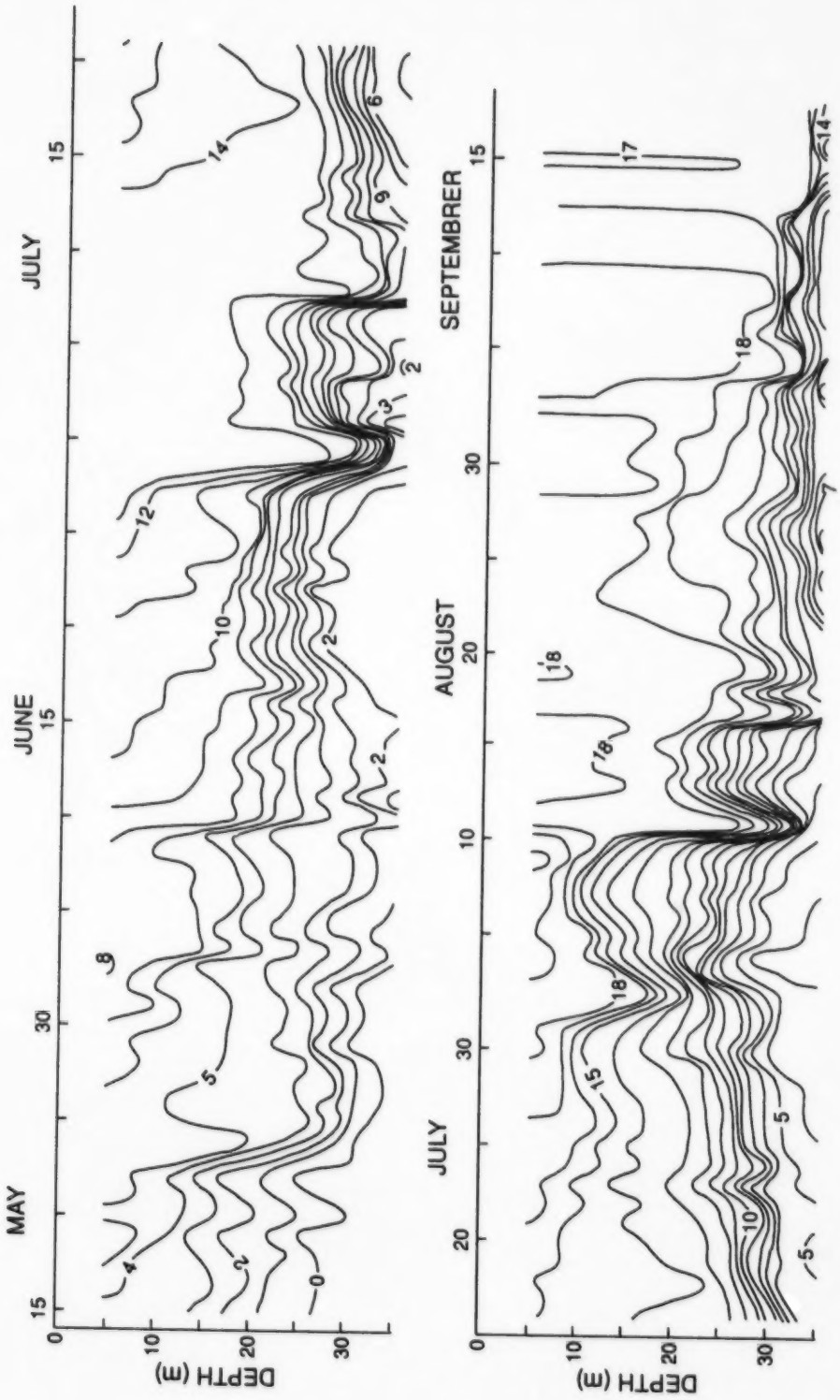

Fig. 12. The variability in the depth of the isotherms during 1980 at T1.

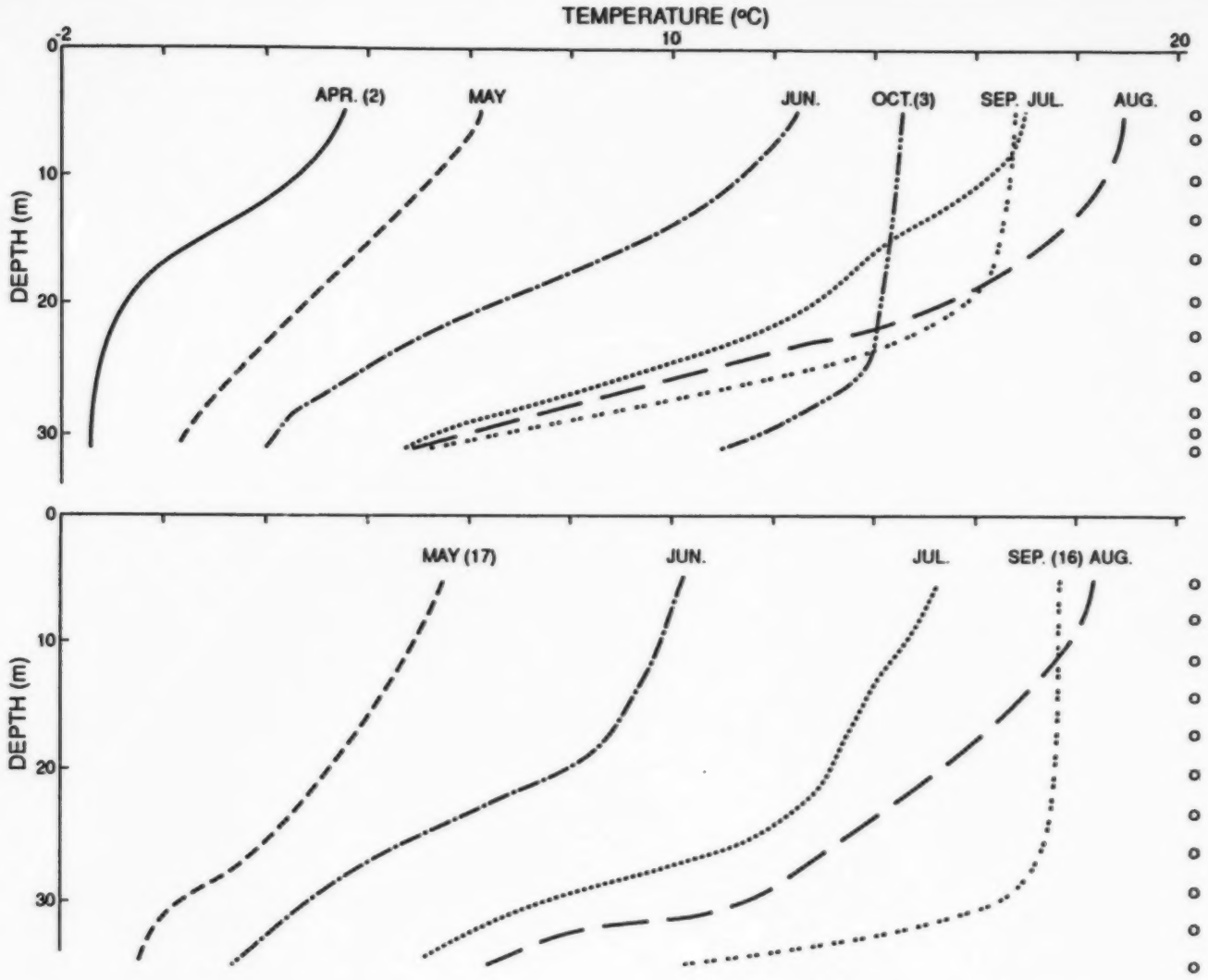

Fig. 13. Monthly mean temperature profiles at T1 in 1979 (top) and 1980 (bottom). The open circles to the right of the diagram indicate the depths of the thermistors used to generate the profile. The number of days used to calculate the monthly means is shown in brackets. Months without numbers indicate data were available for the entire month.

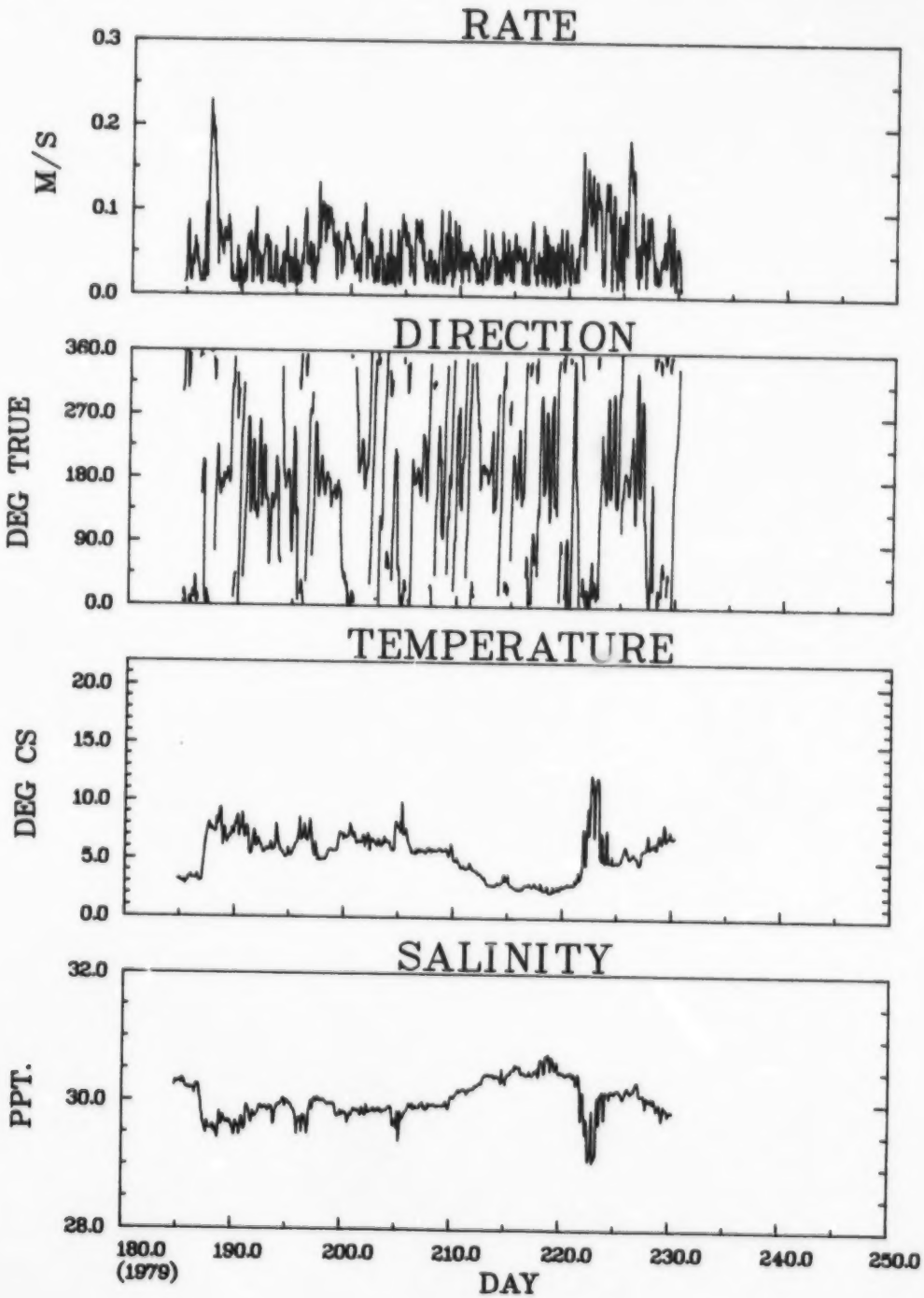

Fig. 14. The time series of rate, direction, temperature, and salinity at T2, 32 m. The time axis is in Julian days (day 180 is June 29).

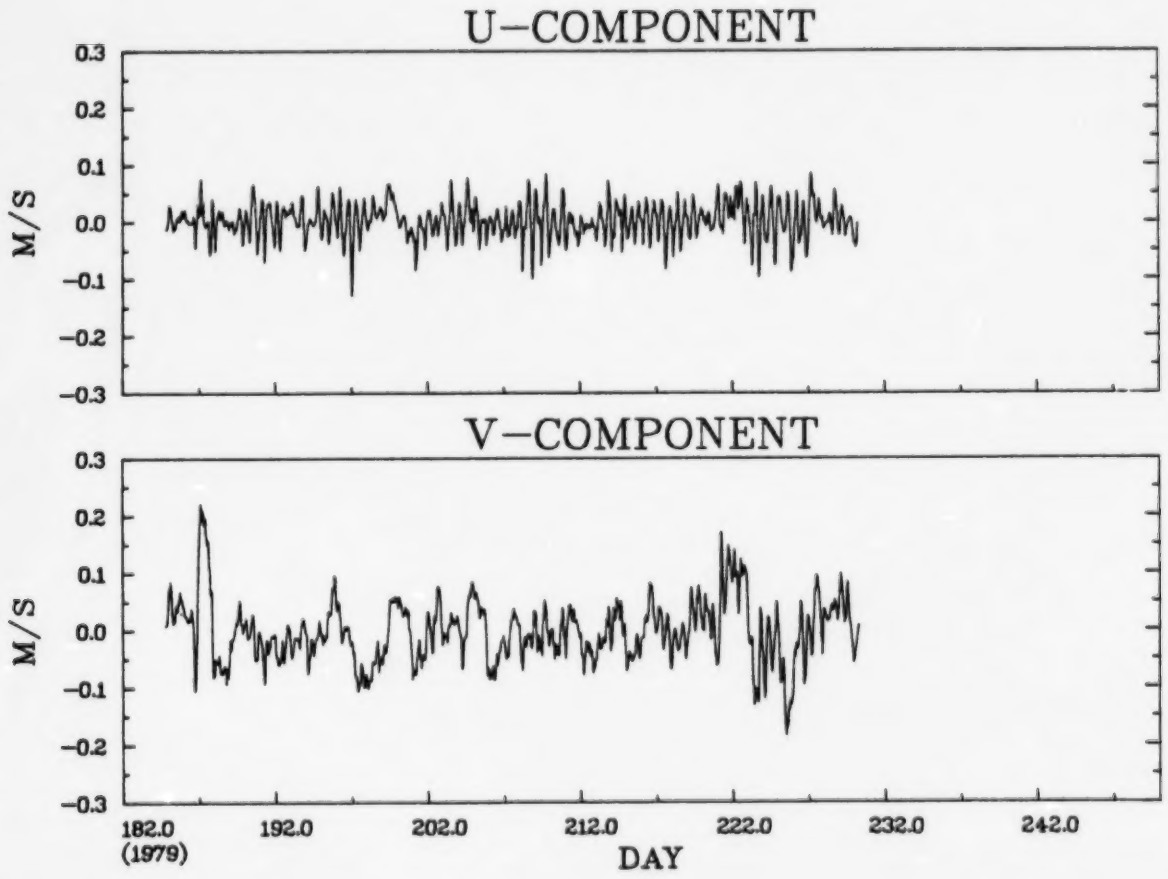

Fig. 15. The time series of the velocity components at T2, 32 m. The positive U is eastwards, the positive V is northwards. The time axis is in Julian days (day 182 is July 1).

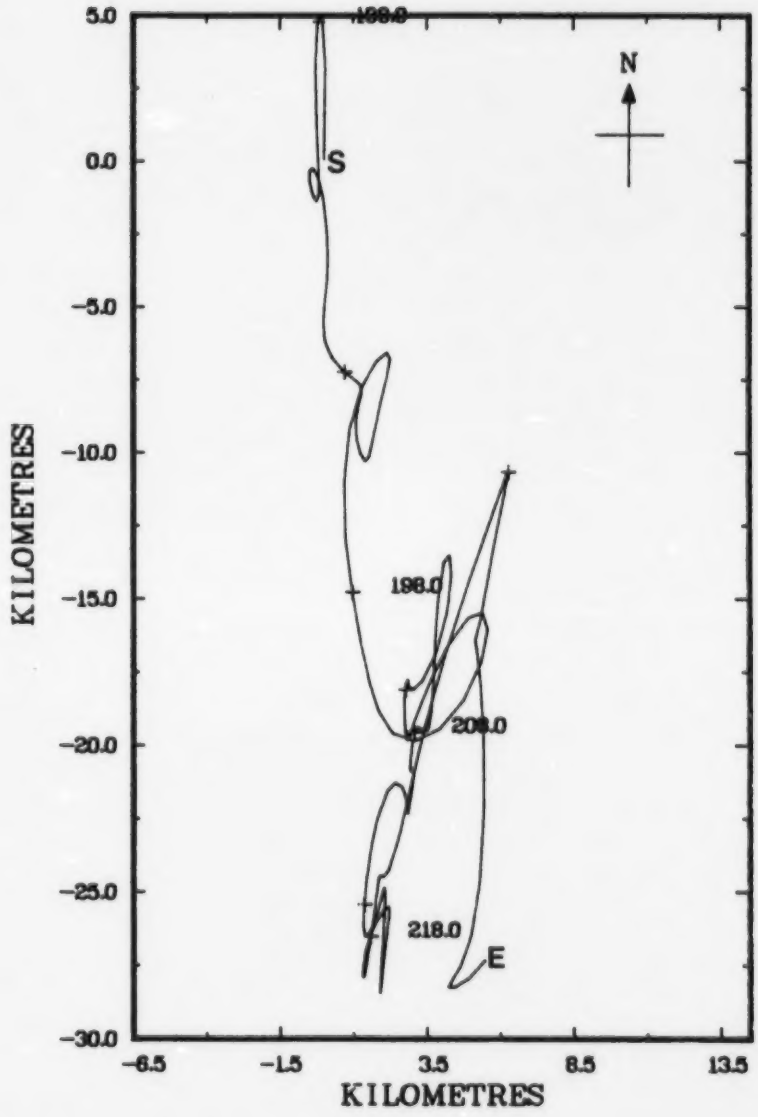

Fig. 16. The progressive vector diagram based on currents measured at T2, 32 m. S and E denote the start and end locations, respectively. Crosses are plotted every 5 d and labelled in Julian days every 10 d. Day 198 is July 17.

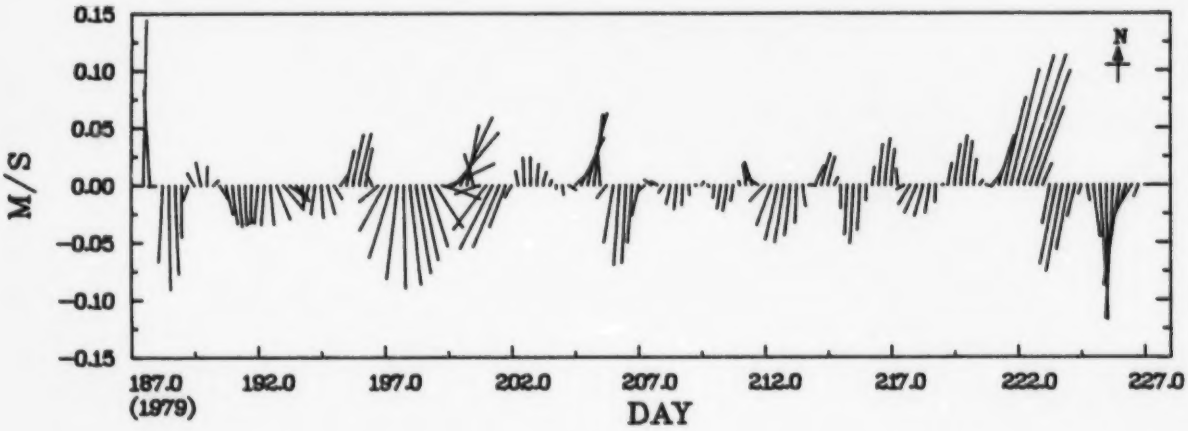

Fig. 17. Stick plot for T2, 32 m. The direction from the axis to the end of the line is that towards which the water is moving. The time axis is in Julian days (day 187 is July 6).

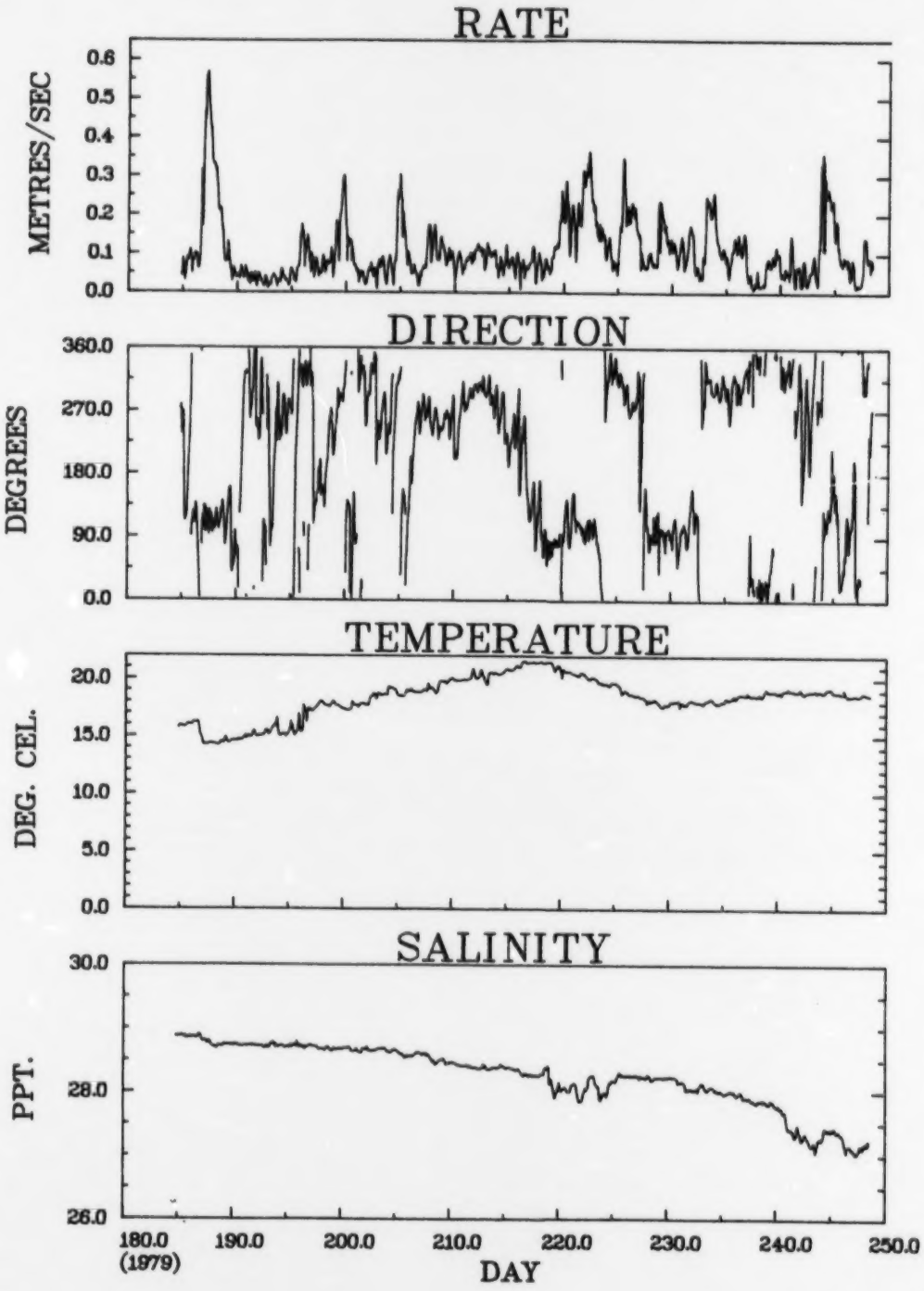

Fig. 18. The time series of rate, direction, temperature, and salinity at T3, 7 m. The time axis is in Julian days (day 180 is June 29).

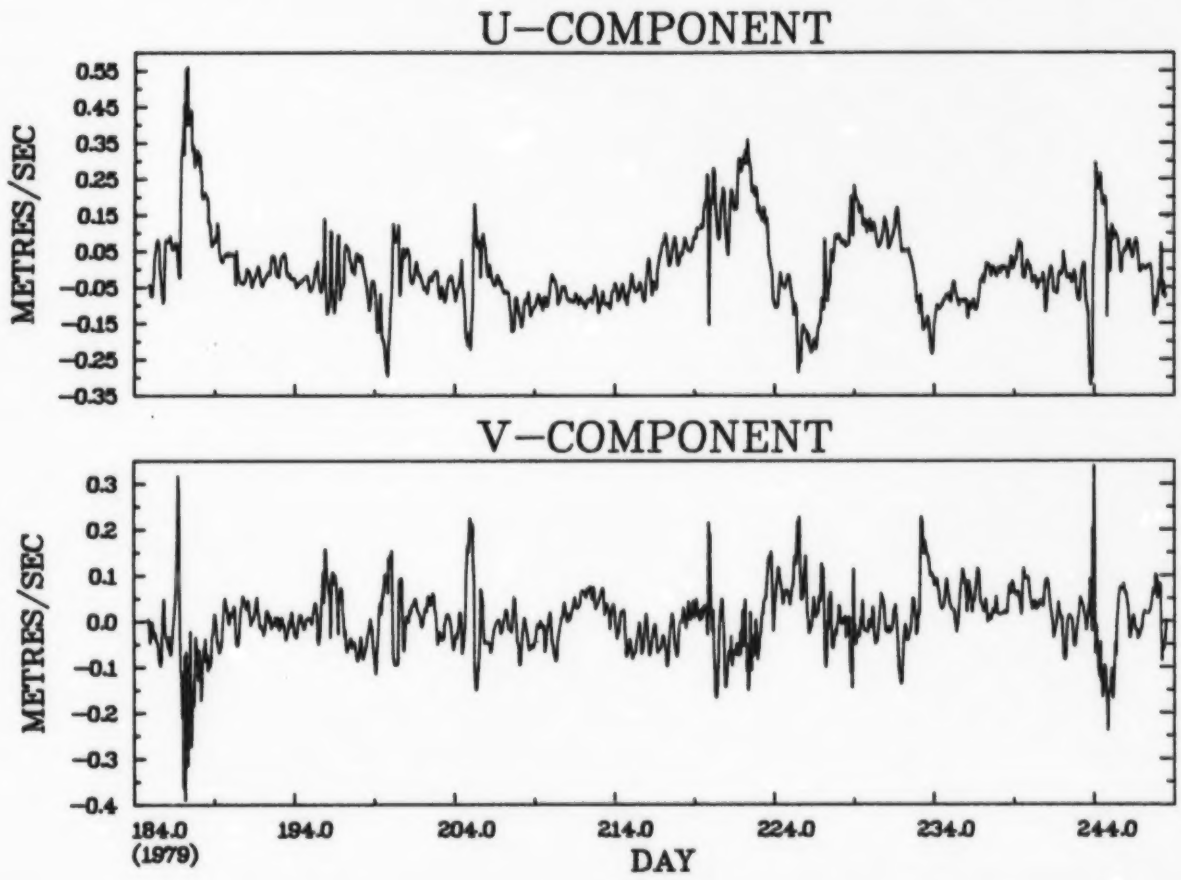

Fig. 19. The time series of the velocity components at T3, 7 m. The positive U is eastwards, the positive V is northwards. The time axis is in Julian days (day 184 is July 3).

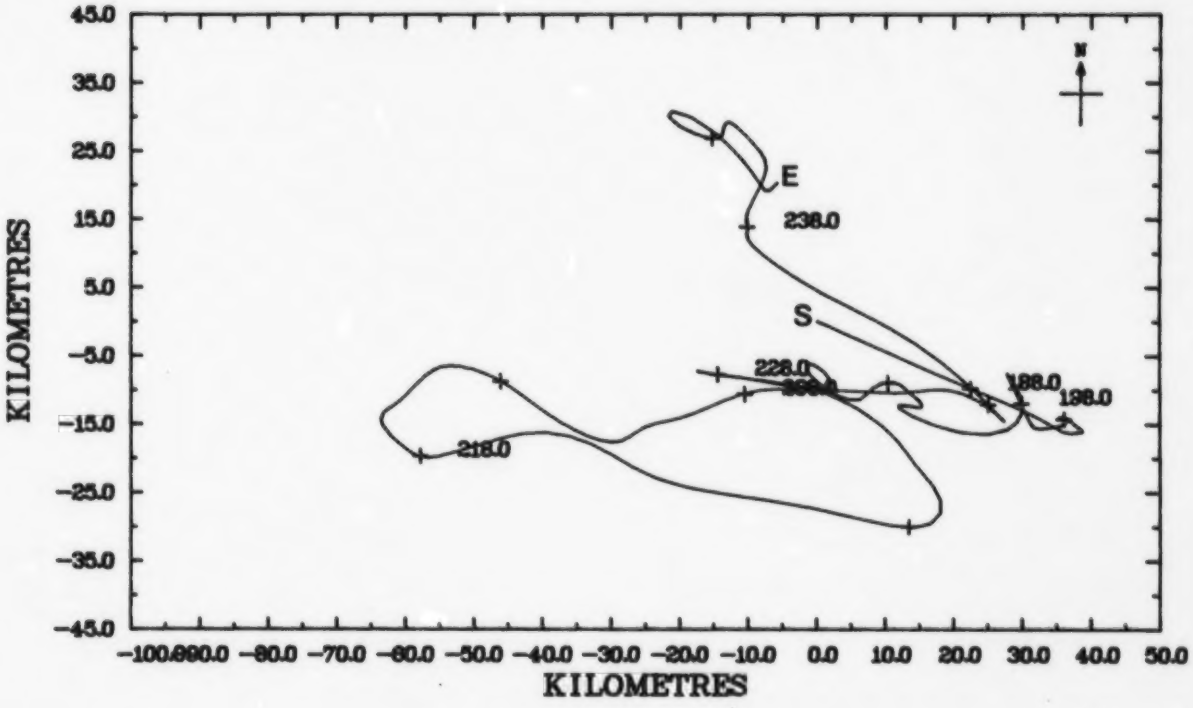

Fig. 20. The progressive vector diagram based on currents measured at T3, 7 m. S and E denote the start and end locations, respectively. Crosses are plotted every 5 d and labelled in Julian days every 10 d. Day 188 is July 7.

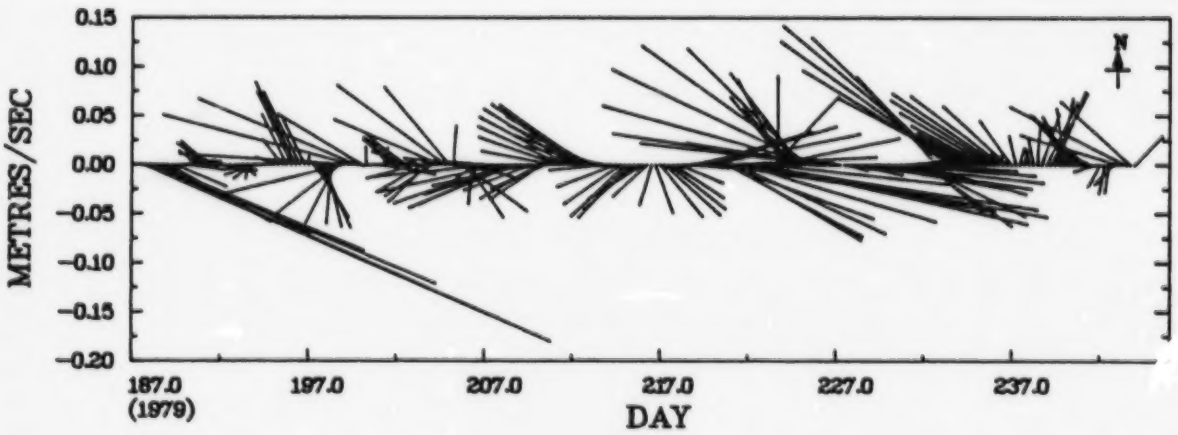

Fig. 21. Stick plot for T3, 7 m. The direction from the axis to the end of the line is that towards which the water is moving. The time axis is in Julian days (day 187 is July 6).

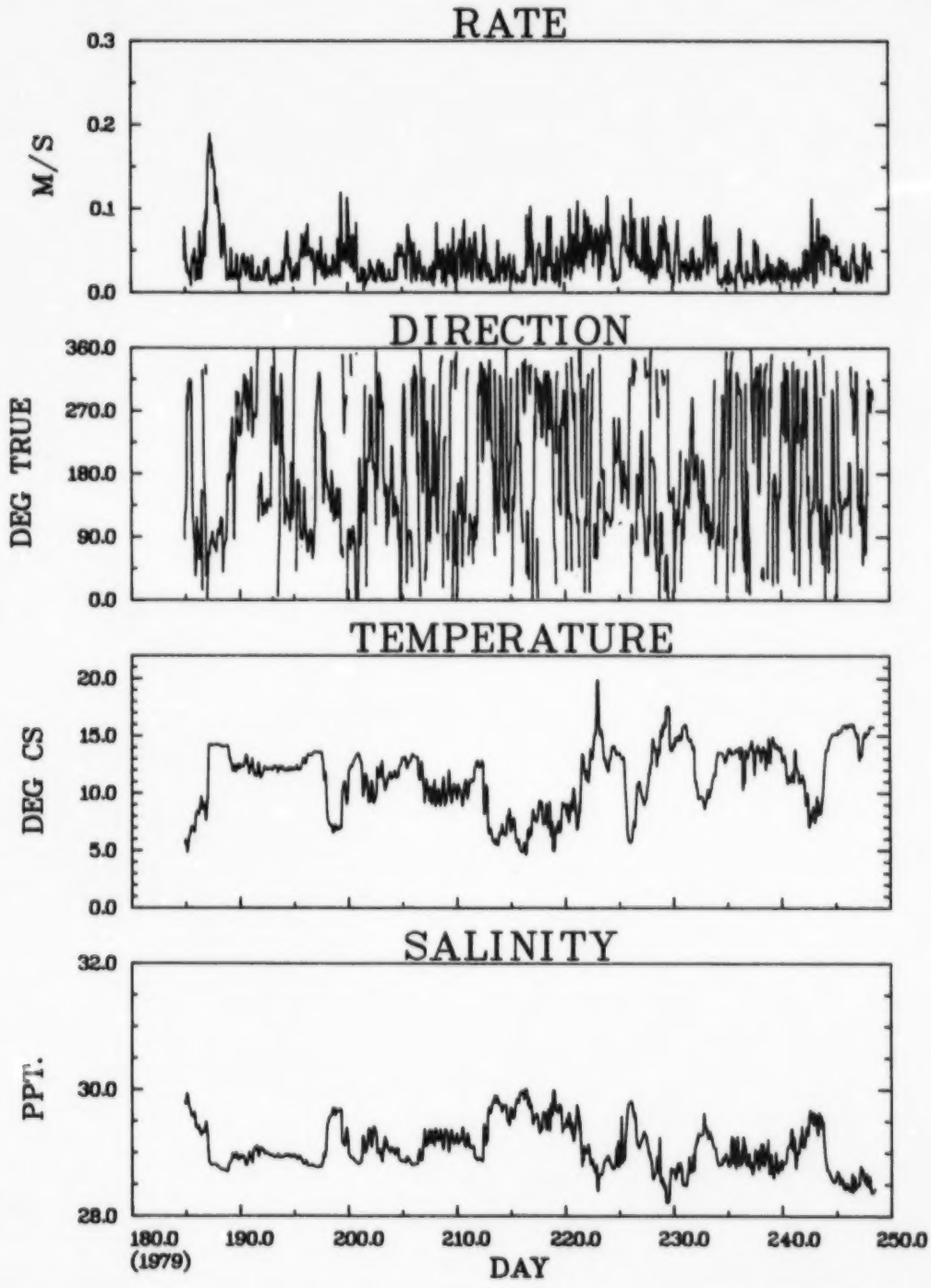

Fig. 22. The time series of rate, direction, temperature, and salinity at T3, 24 m. The time axis is in Julian days (day 180 is June 29).

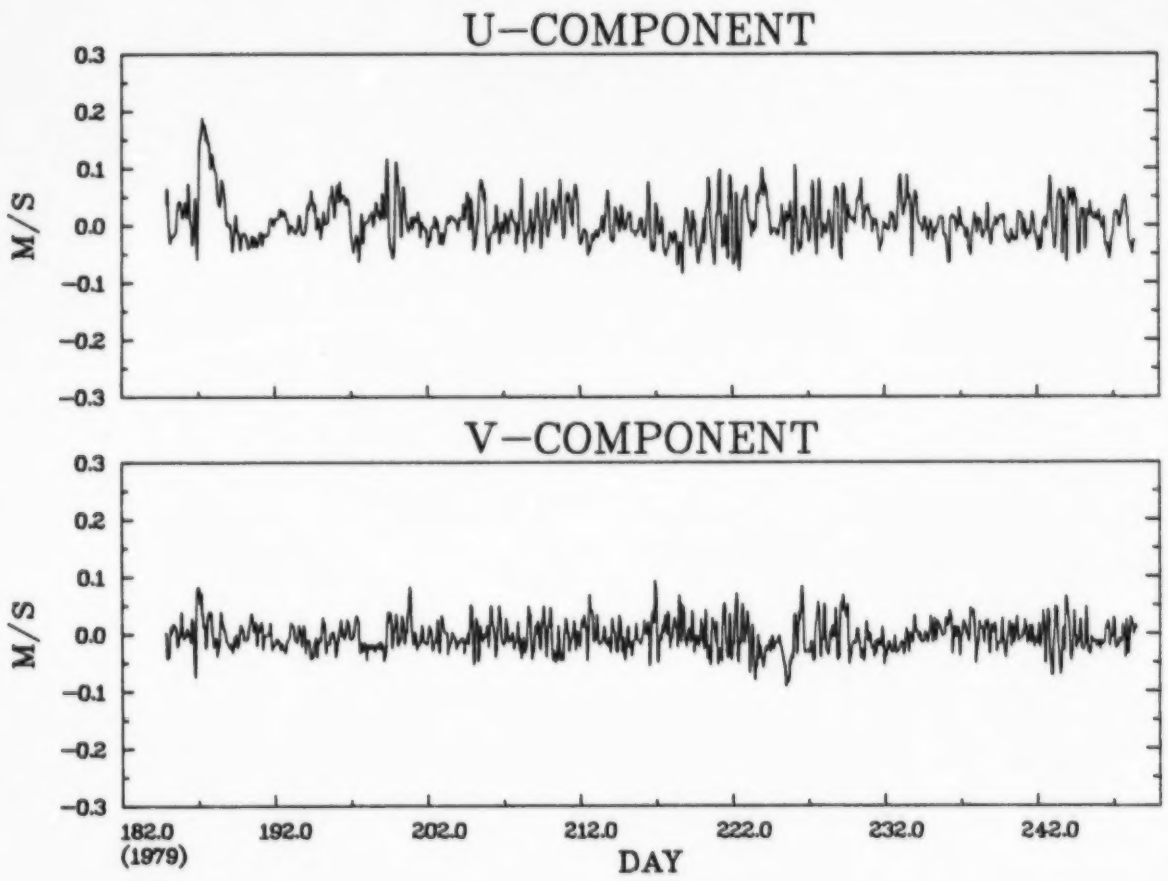

Fig. 23. The time series of the velocity components at T3, 24 m. The positive U is eastwards, the positive V is northwards. The time axis is in Julian days (day 182 is July 1).

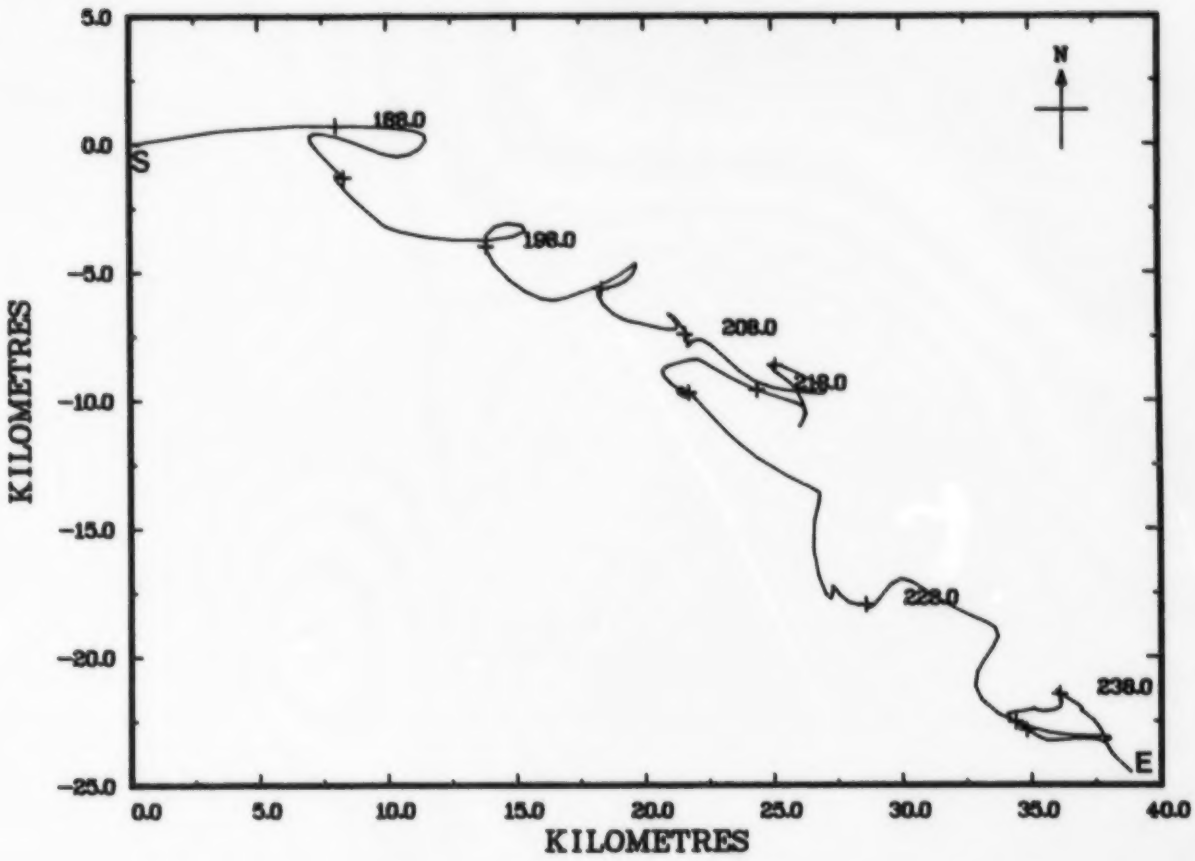

Fig. 24. The progressive vector diagram based on currents measured at T3, 24 m. S and E denote the start and end locations, respectively. Crosses are plotted every 5 d and labelled in Julian days every 10 d. Day 188 is July 7.

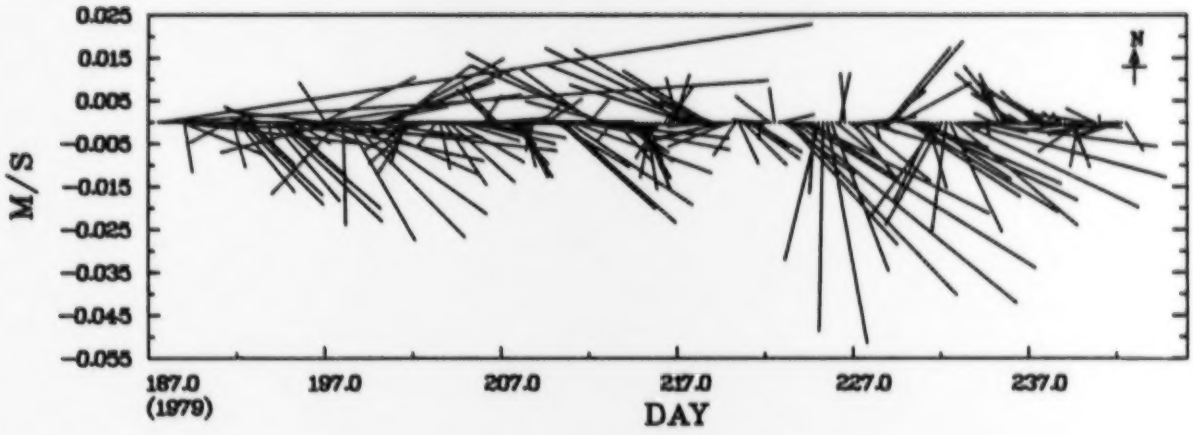

Fig. 25. Stick plot for T3, 24 m. The direction from the axis to the end of the line is that towards which the water is moving. The time axis is in Julian days (day 187 is July 6).